Fishery Data Series No. 99-40

Abundance and Composition of Arctic grayling in the Delta Clearwater River, 1998

William P. Ridder

December 1999

Alaska Department of Fish and Game **Division of Sport Fish**

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
metric ton	mt
milliliter	ml
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
ounce	oz
pound	lb
quart	qt
yard	yd

Spell out acre and ton.

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
minute	min
second	s

Spell out year, month, and week.

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.
All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.
and	&
at	@
Compass directions:	
east	E
north	N
south	S
west	W
Copyright	©
Corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
et alii (and other people)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.,
id est (that is)	i.e.,
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
number (before a number)	# (e.g., #10)
pounds (after a number)	# (e.g., 10#)
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S. state and District of Columbia abbreviations	use two-letter abbreviations (e.g., AK, DC)

Mathematics, statistics, fisheries

alternate hypothesis	H_A
base of natural logarithm	e
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	F, t, χ^2, etc.
confidence interval	C.I.
correlation coefficient	R (multiple)
correlation coefficient	r (simple)
covariance	cov
degree (angular or temperature)	°
degrees of freedom	df
divided by	÷ or / (in equations)
equals	=
expected value	E
fork length	FL
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$\log_2$, etc.
mideye-to-fork	MEF
minute (angular)	'
multiplied by	x
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
standard length	SL
total length	TL
variance	Var

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ABUNDANCE AND COMPOSITION OF ARCTIC GRAYLING IN THE DELTA CLEARWATER RIVER, 1998

by

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ABSTRACT

A mark-recapture experiment was conducted along the lower 14 miles of the Delta Clearwater River over two weeks during the middle of July 1998 to estimate abundance and composition of Arctic grayling *Thymallus arcticus*. Hook and line methods using jigs, flies, and spinners as terminal gear captured 2,443 fish. Estimated abundance of Arctic grayling ≥240 mm FL was 5,570 fish (SE = 780). Quality sized and larger fish (≥270 mm FL) predominated. Age-5 fish are fully recruited to the sampling gear and prior years' fisheries. Age-5 fish comprised 30% (SE 2%) of the population ≥240 mm FL while age-4 and 6 comprised 14% (SE = 2%) each. Jig marked fish had significantly lower capture probabilities than fly marked fish and therefore were excluded from the experiment. A positive bias of 8% resulted when jig marked fish were included in the experiment.

Key words: Arctic grayling, *Thymallus arcticus,* abundance, age composition, size composition, gear shyness, hook shyness, hook and line, capture probability, Delta Clearwater River, Alaska.

INTRODUCTION

The Delta Clearwater River (DCR) is a 21 mi spring-fed system located 110 mi southeast of Fairbanks and 14 mi northeast of Delta Junction in the middle Tanana River drainage (Figure 1). It is the largest and most accessible of a number of spring-fed systems which head in alluvial deposits on the south side of the drainage. The larger of these systems provide quality summer feeding habitat for Arctic grayling; however, these fish neither spawn or overwinter in these systems (Reed 1961; Tack 1980; Ridder 1991). The DCR Arctic grayling fishery is unique among the major road accessible fisheries in the drainage because it is composed of fish that spawn in at least eight different systems (Ridder 1998a). Immigration to the DCR begins in April with juvenile fish, followed by adults, and continues into June. Emigration begins in August and is complete by December.

Since becoming road accessible in 1953, the DCR has offered a small but productive and popular Arctic grayling fishery known for its high catch rates, large Arctic grayling, and pristine water quality. The harvest of Arctic grayling has been predominantly age-5 and older fish. Prior to 1987, average annual harvests of 5,700 fish ranked the DCR in the top five Arctic grayling fisheries in the Tanana drainage (Table 1). Drainage-wide declines in harvest and abundance indices in the middle 1980s led to restrictive regulations for the DCR and other drainage fisheries in 1987. These regulations included a catch and release season from 1 April to the first Saturday in June, a 305 mm TL minimum size limit, a no bait restriction, and five fish daily bag and possession limit (limits were 10 fish daily and 20 fish in possession prior to 1977 and five and 10, respectively, through 1986). From 1987 through 1994, average annual harvest declined to 1,800 fish (Table 1). Results from CAGEAN modeling of the fishery from 1977-1990 and other studies from 1995 and 1996 led to further restrictions to the fishery in 1995 and 1997. A two fish bag and possession limit imposed in July of 1995 through 1996 lowered average annual harvest to 940 fish. The fishery became catch and release in June of 1997.

Two programs to enhance the Arctic grayling fishery in the DCR ran from 1974 through 1979 and 1983 through 1987. Through these enhancement programs, the river was stocked with 10-brood years of Arctic grayling totaling 567,786 fish (Appendix A1). The majority, 400,000 fish, was stocked as fry in 1974 and 1975. These stockings were considered failures and subsequent stockings, 164,355 fish, were of fish reared for three months in shallow ponds or at Clear Hatchery. Limited stocking of age-1 fish also occurred (n = 3,431). Between 1978 and 1990,

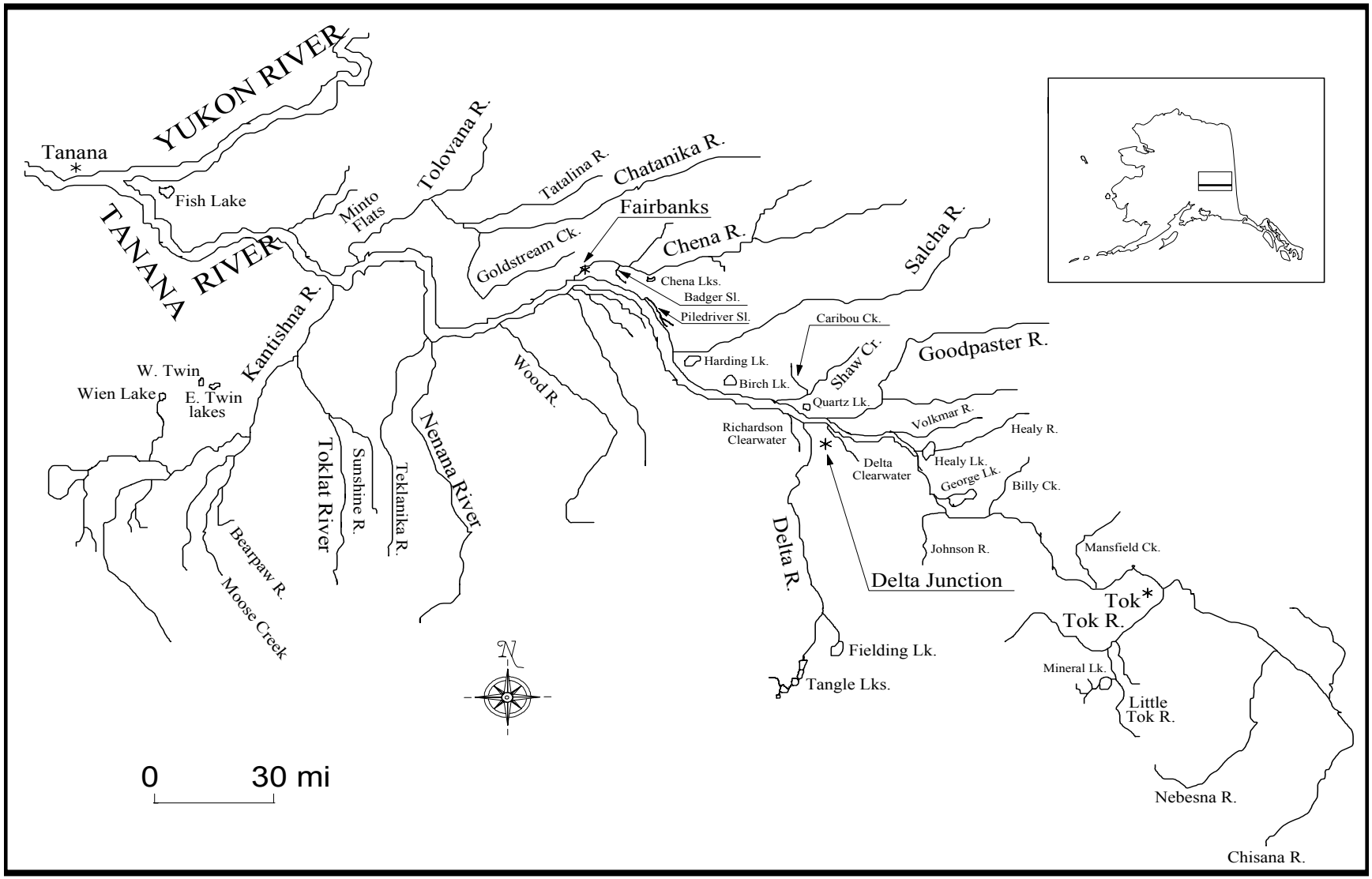

Figure 1.-The Tanana River drainage.

Table 1.-Estimates of harvest and effort in the fisheries of the Delta Clearwater River from the Statewide Harvest Survey, 1977-1997 (Mills 1978-1994; Howe et al. 1995-1998).

			Arctic grayling		Coho	
Year	Anglers[a]	Days Fished[a]	Harvest	Catch	Harvest	Catch
1977	na[b]	6,881	6,118	na	31	na
1978	na	7,210	7,657	na	126	na
1979	na	8,398	6,492	na	0	na
1980	na	4,240	5,680	na	25	na
1981	na	4,673	7,362	na	45	na
1982	na	4,231	4,779	na	21	na
1983	na	5,867	6,546	na	63	na
1984	2,024	5,139	4,193	na	571	na
1985	2,947	8,722	5,809	na	722	na
1986	3,693	10,137	2,343	na	1,005	na
1987[c]	3,068	5,397	2,005	na	1,068	na
1988[c]	2,413	5,184	2,910	na	1,291	na
1989[c]	2,845	5,368	3,016	na	1,049	na
1990[c]	2,498	4,853	1,772	12,424	1,375	3,271
1991[c]	3,171	5,594	2,165	7,998	1,721	4,382
1992[c]	1,770	3,756	797	6,086	615	1,555
1993[c]	1,491	4,909	437	5,712	48	1,695
1994[c]	2,100	3,984	1,411	9,306	509	3,009
1995[c,d]	2,927	6,261	926	5,974	391	5,195
1996[d]	2,523	4,622	957	9,448	983	2,543
1997[e]	1,866	2,925	30	4,665	866	4,174
			Averages			
1977-1997	2,524	5,636	3,495	7,702	596	3,228
1977-1986	2,888	6,550	5,698	na	261	na
1987-1994[c]	2,420	4,881	1,814	8,305	960	2,782
1995-1996[d]	2,725	5,442	942	7,711	687	3,869

[a] Anglers and days fished represents effort on all species.

[b] na = not available.

[c] Regulations for 1987 through June 1995 changed from no closed season and a five fish bag and a 10 fish possession limit to catch-and-release fishing from 1 April until the first Saturday in June; a 305 mm (12 inch) minimum length limit; a five fish bag and possession limit; and, a restriction of terminal gear to unbaited artificial lures.

[d] The daily bag and possession limits were reduced from five fish to two fish in July 1995 through 1996.

[e] In June 1997, the Delta Clearwater River and its tributaries were closed to possession of Arctic grayling from 1 January through 31 December.

stocked fish[1] accounted for 2% to 24% of the harvest and averaged 13% (Ridder 1985; *Unpublished*). Stocked fish were predominantly harvested at ages 2 to 4 due to a larger size at age than "wild" fish. Stocked fish, age-5 and older, averaged 4% of the total harvest and 10% of the age-5 and older harvest.

Stock assessments on the DCR have historically been monitoring programs centered on creel surveys, age and length sampling, and relative abundance indices (the catch rate from one downstream pass of an electrofishing boat; Peckham and Ridder 1979, Ridder 1985). While these assessments were capable of detecting population trends, they did not give estimates of abundance, recruitment, survival and exploitation from which to actively manage the fishery. CAGEAN modeling (Clark and Ridder 1994) provided the first look into the dynamics of the DCR population. A study was conducted from 1995 through 1997 to investigate one major assumption of the model, geographic closure, by quantifying fidelity to the DCR (Ridder 1998a). The study determined that the DCR population could be classified as a unit stock due to a high level of fidelity (98%, SE = 3%; Ridder 1998a) and satisfied the model's assumption. Studies estimating the abundance of the DCR population with Peterson mark-recapture methodology were conducted in 1996 and 1997 to document the population's response to regulatory changes (Ridder 1998b). This study continues the abundance estimation with similar methodology.

Specific objectives of Project F-10-14, Job R-3-2(c) were to estimate:

1. abundance of Arctic grayling (≥150 mm FL) in the lower 17 mi of the Delta Clearwater River, such that this estimate is within 25% of the true abundance 95% of the time;
2. age composition of the Arctic grayling (≥150 mm FL) in the lower 17 mi of the Delta Clearwater River, such that all proportions are within 5 percentage points of the true proportions 95% of the time; and,
3. length composition of the Arctic grayling (≥150 mm FL) in the lower 17 mi of the Delta Clearwater River, such that all proportions are within 5 percentage points of the true proportions 95% of the time.

The study also investigated differences between capture probabilities of fly and jig marked fish. In addition, age and size composition of all captured fish from 1996 through 1998, hook and line catch rates for 1998, and a summary of estimates of abundance and recruitment from 1977 through 1998 are given in Appendix A to provide comparisons with historical data from the DCR.

METHODS

Arctic grayling were historically present up to mile 17 of the Sawmill Creek fork of the DCR while few, if any, Arctic grayling have inhabited the North Fork (Peckham and Ridder 1979; Figure 2). However, from creel interviews and intermittent surveys by Alaska Department of

[1] Stocked fish were discriminated from wild fish by physical characteristics fin clip (for brood years 1983-86) and high circular counts on scales from brood years 1975-1979; (Ridder 1985).

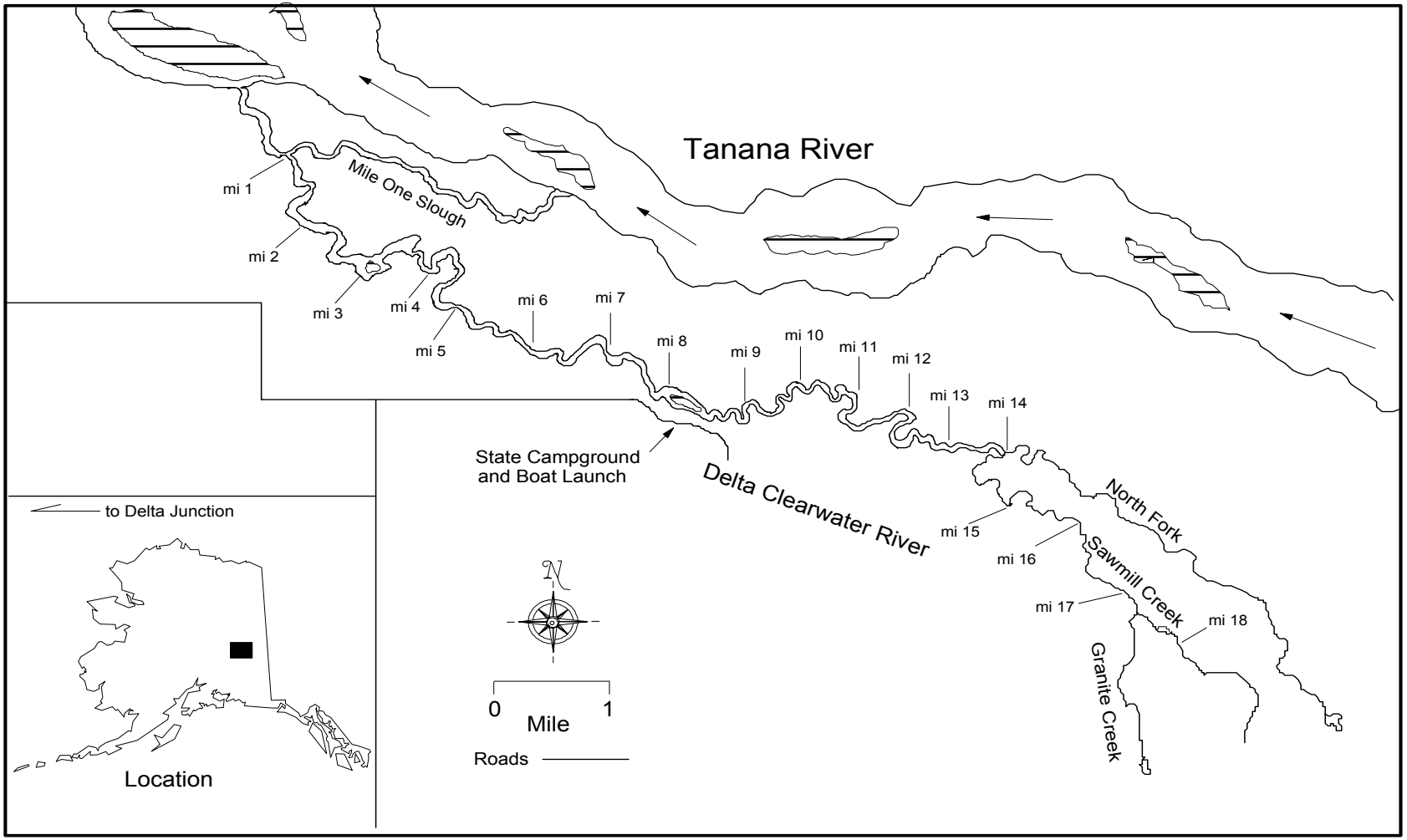

Figure 2.-The Delta Clearwater River.

Fish and Game (ADFG), few grayling have been present in the Sawmill Creek fork since the late 1980's through 1995 (Ridder, *unpublished*). Prior to mark-recapture experiments in 1996 and 1997, no fish of any species were observed above mile 15. Less than 10 Arctic grayling in 1996 and 30 Arctic grayling in 1997 were observed in the one-mile section downstream of mile 15. For the mark-recapture experiment, the upper boundary was set at mile 14 for both years (Ridder 1998c). The upper boundary was again set at mile 14, even though approximately 50 Arctic grayling were observed on 10 July 1998 from mile 14 to mile 15 with no fish upstream of mile 15. The lower boundary for all years was set at mile 1 where a side slough of the silt laden Tanana River enters the river during the summer and causes the lower river to become turbid and not fishable.

The study area was divided in two different ways for comparison to historical information and for investigating bias. For comparisons to historical data, catch and effort data that is presented in the appendices are stratified into two sections at mile 8. Above mile 8, the river is distinctly more shallow and narrow than below. Mile 8 is also the location of the river's sole state campground and public boat launch. Creel surveys from 1976 through 1990 have used the boat launch as a boundary in recording angler use, preference, catch rates, and age and length compositions of the harvest. For investigating bias due to movement and capture probabilities, the river is divided into three sections: Section 1, miles 2 – 5; Section 2, miles 6 – 10 and; Section 3, miles 11 – 14.

Three 5-d sampling events were conducted in 1998. The first two events occurred between 13 and 24 July, were separated by a 2-d hiatus, and comprised the two-event Peterson mark-recapture experiment. The third event occurred two weeks later from 10 to 14 August and provided data for calculation of survival rate using the Jolly-Seber model and for comparisons of capture probabilities of marked fish from the first event recaptured in the second and third events. In all events, five two-man crews were positioned along the study area beginning at mile 14. Crews were made up of volunteer and ADFG personnel. Each crew proceeded downstream fishing each pool and run in a systematic manner usually covering less than a mile per day. Their capture gear was hook-and-line, primarily with dry flies, white crappie "mini" jigs, and, to a much lesser extent, small spinners. Crews selected terminal gear at their discretion. All captured Arctic grayling were processed immediately or soon after capture, marked with a Floy FD 94 anchor tag and a partial fin-clip and then released at, or very near, their capture site. Processing involved collecting data on date, location, crew, tackle type (fly, jig, or spinner), length, scale samples, old finclips, tag number and color, recapture status, and mortality. Data were recorded on scale sample envelopes or field forms and later transferred to mark sense forms. These were transformed into an electronic (ASCII) data file for analysis and archival (see listing of data files in Appendix B1).

Estimates of abundance were derived for three components of the population. The first component was to estimate abundance for fish ≥150 mm FL. However, sampling results constrained this component to fish that were greater than or equal to the length of the smallest fish recaptured. This component was further stratified by gear type to investigate hook shyness (see below). The second component was and is necessary for comparisons to historical sample and harvest data (for the population ≥ 270 mm FL). This length is approximately equal to the minimum length for harvest in the fishery (305 mm TL) and approximates the adult component of the population (see Clark 1992). The third component was for age-5 and older fish. This

component was used for CAGEAN estimates and was based on the age at full recruitment to the population and fishery (see Clark and Ridder 1994). The abundance of latter two components were estimated proportionately from the first component.

ESTIMATION OF ABUNDANCE

The mark-recapture experiment was designed to satisfy the assumptions of a Petersen mark-recapture experiment (Seber 1982). These assumptions were that:

1. the population was closed (no change in the number or composition of Arctic grayling in the population during the experiment);
2. all Arctic grayling had the same probability of capture in the first sample or in the second sample, or marked and unmarked Arctic grayling mixed uniformly between the first and second samples;
3. marking of Arctic grayling did not affect their probability of capture in the second sample;
4. Arctic grayling did not lose their mark between sampling events; and,
5. all marked Arctic grayling were reported when recovered in the second sample.

Testing of Assumptions

Assumption 1 was implicitly assumed because of the size of the study area, the short duration of the experiment (the middle two weeks of July), and results from other studies. Tack (1973) found little movement of Arctic grayling during the mid-summer feeding period in a six-month study of a 150-mi reach of the Goodpaster River. In a two-year radiotelemetry study (Ridder 1998a; *Unpublished*) found that 37 of 39 Arctic grayling, after spawning in six streams, emigrated to the Clearwater by 5 June and 38 of the 39 fish by 23 June. In the same study, movement out of the river was not detected until 6 August in 1995 and 15 August in 1996. Thus, the large section of river and the time of year reduced the probability of significant numbers of fish entering or leaving the study area between sampling events. The short duration reduced the likelihood that mortality or recruitment due to growth occurred between sampling events.

The validity of assumption 2 and 3 was tested by comparing recapture rates and movements of fish between events with tests of consistency designed to detect unequal catchability by area and by size of fish (Seber 1982, Bernard and Hansen 1992). The validity of assumptions 4 and 5 were ensured by distinctive and permanent marking and rigorous examination of all captured fish.

Tests indicated that assumption 2 was not valid for this experiment due to unequal mixing of fish, unequal catchability of fish, and non-uniform sampling during both events. By default, the Darroch estimator of abundance was used in place of the Petersen since this estimator does not require the validity of assumption 2 (Darroch 1961).

Calculation of Abundance

Maximum likelihood (ML) estimates of the Darroch likelihood were found by the direct searching algorithm of Hooke and Jeeves (M. Wallendorf, Alaska Department of Fish and Game, Fairbanks, personal communication). The ML estimator required that for each tagging location,

the movement probabilities were restricted to sum to 1 (consistent with the closure assumption). The objective function for the natural log of the Darroch likelihood was:

$$L = \sum_i \{(a_i - c_{i\cdot}) \log[1 - \sum_j \Theta_{ij} p_j]\} + \sum_i \sum_j c_{ij} \log(\Theta_{ij} p_j), \quad (1)$$

where:

a_i = number of fish tagged at location i;

c_{ij} = number tagged fish from location i recaptured at location j;

$c_{i\cdot} = \sum_j c_{ij}$;

p_j = second sample capture probability for location j; and,

Θ_{ij} = probability of movement from tagging location i to recapture location j.

The estimate of untagged fish in the jth location of the second sample was:

$$\tilde{n}_j = b_j / \hat{p}_j \quad (2)$$

where b_j was the number of untagged fish caught in the second sample.

Total abundance was:

$$\tilde{N} = \sum_j \tilde{n}_j + \sum_i a_i \, . \quad (3)$$

The covariance matrix for the capture probabilities and movement probabilities were estimated using the observed information matrix. The variance for the abundance estimate was then approximated using the delta method (Seber 1982).

ESTIMATION OF AGE AND SIZE COMPOSITION

For aging, scales were taken from the area approximately six scale rows above the lateral line just posterior to the insertion of the dorsal fin (W. Ridder *Unpublished*; Brown 1943). Scales were processed by wiping slime and dirt off each scale and mounting on gummed cards. The gum cards were used to make triacetate impressions of the scales (30 s at 137,895 kPa, at a temperature of 97ºC). Ages were determined by counts of annuli from the triacetate impressions magnified to 40X with a microfiche reader. Criteria for determining annuli were: 1) complete circuli cutting over incomplete circuli; 2) clear areas or irregularities in circuli along the anterior and posterior fields; and, 3) regions of closely spaced circuli followed by a region of widely spaced circuli (Kruse 1959). Age composition was described with proportions of the stock contained in each age class. Size composition of Arctic grayling was described with the incremental Relative Stock Density (RSD) indices of Gabelhouse (1984). The RSD categories of Gabelhouse are: "stock" (150 to 269 mm FL); "quality" (270 to 339 mm FL); "preferred" (340 to 449 mm FL); "memorable" (450 to 559 mm FL); and, "trophy" (greater than 559 mm FL).

From tests of assumptions 2 and 3 for estimation of abundance, significant differences in capture probability by area were found. Differences in capture probability may also bias estimates of age

and size compositions. Age and size data were adjusted for these differences so that the age and size composition of Arctic graying in the lower 14 mi of the Delta Clearwater River could be estimated. First, the proportions of fish by age class or size category were estimated for each stratum used in estimation of abundance:

$$\hat{p}_{ik} = \frac{n_{ik}}{n_i} \tag{4}$$

where:

$\hat{p}_{ik}$ = the estimated proportion in age or size category k fish sampled in stratum i;

n_{ik} = the number of age or size category k fish sampled in stratum i; and,

n_i = the number of fish sampled in stratum i.

Variance of this proportion was estimated using the variance of a binomial, $\hat{V}[\hat{p}_{ik}] = \frac{\hat{p}_{ik}(1-\hat{p}_{ik})}{n_i}$.

Next the abundance of each age class or size category was estimated from the proportions and abundance in each stratum:

$$\hat{N}_{ik} = \hat{p}_{ik}\hat{N}_i \tag{5}$$

where:

$\hat{N}_{ik}$ = the estimated abundance of age or size category *k* fish sampled in stratum *i*.

Variance of each abundance at age or size was estimated with the formula for the variance of the product of two independent variables (Goodman 1960):

$$\hat{V}\left[\hat{N}_k\right] = \hat{p}_k^2\hat{V}\left[\hat{N}\right] + \hat{N}^2\hat{V}[\hat{p}_k] - \hat{V}\left[\hat{N}\right]\hat{V}[\hat{p}_k]. \tag{6}$$

After calculating abundance at age or size in each stratum, the overall proportions were estimated by:

$$\hat{p}'_k = \sum_{i=1}^{s} \frac{\hat{N}_i}{\hat{N}_{ALL}}\hat{p}_{ik} \tag{7}$$

where:

$\hat{p}'_k$ = the estimated weighted proportion of Arctic grayling in the lower 14 river mi of the Delta Clearwater River that were age or size *k*.

Variance of the proportions were approximated with the delta method (see Seber 1982):

$$\hat{V}[\hat{p}'_k] \approx \sum_{i=1}^{s} \frac{(\hat{p}_{ik} - \hat{p}'_k)^2\ \hat{V}[\hat{N}_i]}{\hat{N}_{ALL}^{\ 2}} + \sum_{i=1}^{s}\left(\frac{\hat{N}_i}{\hat{N}_{ALL}}\right)^2 \hat{V}[\hat{p}_{ik}]. \tag{8}$$

These estimated weighted proportions and variances by age and size were used as estimates of age and size compositions in the lower 14-river mi of the Delta Clearwater River.

HOOK SHYNESS

Reactions of fish to capture methods can affect their subsequent recapture through either avoidance behavior (gear shyness) or attraction (gear happiness). In mark recapture experiments, these reactions bias estimates. In this study, gear shyness to the capture method in general and, specifically, gear type (flies and jigs) was investigated with three sampling events. Contingency tests of capture probabilities and recaptures rates of fish released in the first event and recaptured in the second and third events and survival rate between the first and second events were used to infer gear reactions. The modified Jolly-Seber model (Seber, 1982) was used to estimate survival.

RESULTS

In three sampling events in 1998, 2,443 Arctic grayling (≥ 150 mm FL) were captured with 690 angler-hours of effort (Table 2; Appendices A2 and A3). Three percent of these fish (n = 67) were fish caught twice either the same day or within the same event. Of the 2,376 fish that were unique to the events, 299 fish (13%) were recaptures of fish released in earlier events and 157 fish (7%) were recaptures from other studies. The majority of the latter fish were from the Goodpaster River (n = 117 or 5% of the unique catch). Six fish died immediately during the sampling events.

Angling effort came from nine ADFG personnel (58%) and 21 volunteers (42%). Angling effort declined 25% over the study from 264 angler-hours for the first event to 199 angler-hours in the third event (Table 2). The decline was similar between events, 14% from the first to the second event and 12% from the second to third. However, the decline was coupled with an increase in efficiency in CPUE (number of fish per angler-hour), which increased from 3.3 fish per hour in the first event to 3.8 fish per hour in the third event (Appendices A2 through A5).

HOOK SHYNESS

Hook shyness was investigated in fish greater than 240 mm FL to correspond to the assessed population. Of the 2,314 fish ≥240 mm FL caught with hook and line gear in 1998, the majority were caught with flies (n = 1,242) and jigs (n = 975; Appendix A6). The ratio of jig caught fish to fly caught fish significantly declined over the three events ($\chi^2 = 35.18$; df = 2; $P < 0.01$) but were similar in the first (marking) event (jig = 397 and fly = 382; Appendix A6). Fish caught with each gear type was not uniform along the study reach within events or between events (Appendix A7).

Significant differences in capture probability of all marked fish between 7-d and 21-d were not detected (Test 5b Otis et al. 1978 p118: a test for the constancy of capture probability over time, $\chi^2 = 0.001$; df = 1; P = 0.97). Survival rate of these fish between the first two events was not significantly different from unity (S = 1.18, SE = 0.14).

A significant difference in capture probability was detected in comparisons between gear types. The rate of recapture of jig-marked fish was significantly less than fly caught fish in the second event when captured with all gear types ($\chi^2 = 5.63$; df = 1; P = 0.018, Table 3), but not in the third event ($\chi^2 = 0.18$; df = 1; P = 0.67; Table 4).

Table 2.-Summary of catch statistics for Arctic grayling from three sampling events in the Delta Clearwater River, 1998.

Event[a]	Hiatus (d)	Effort (hr)	Area (mi)	Catch			Released				
				Total	Unique[b]	K[c]	≥150	≥240	R[d]	R1[e]	R2[f]
1	---	264	13	867	850	5	845	814	---	---	---
2	5 - 7	227	13	821	800	1	799	779	105	105	---
3	21 - 28	199	14	755	726	0	726	716	194	110	84
	Totals	690	---	2,443	2,376	6	2,370	2,309	299	215	84

[a] Event = 1: 13 - 17 July; 2: 20 - 24 July; 3: 10 - 14 August.

[b] Unique = fish unique to the event, includes recaptures from other events.

[c] K = killed fish..

[d] R.. = total recaptures from all events.

[e] R1 = recaptures from Event 1.

[f] R2 = recaptures from Event 2.

Table 3.-Comparison of recapture rates and capture probabilities of Arctic grayling ≥240 mm FL between two recapture events and grouped by capture gear of the mark event, Delta Clearwater River, July - August 1998.

				Recapture rate (R/M)		Capture probability (R/C)	
Events[a]	M[b]	C[c]	R[d]	R/M	SE[R/M]	R/C	SE[R/C]
All Gear types:							
1 & 2	818	780	105	0.13	0.01	0.13	0.01
1 & 3	818	716	110	0.13	0.01	0.15	0.01
Fly marks only:							
1 & 2	382	780	59	0.15	0.02	0.08	0.01
1 & 3	382	716	53	0.14	0.02	0.07	0.01
Jig marks only:							
1 & 2	397	780	38	0.10	0.01	0.05	0.01
1 & 3	397	716	50	0.13	0.02	0.07	0.01

[a] Events = Event 1: 13 - 17 July; Event 2: 20 - 24 July; Event 3: 10 - 14 August.

[b] M = number of marked fish released alive in first designated event.

[c] C = number of fish examined in second designated event.

[d] R = number of marked fish from first designated event and recaptured in second designated event.

Table 4.-Comparison of recapture rates and capture probabilities of Arctic grayling ≥ 240 mm FL marked with two gears and recaptured by three gear groups, Delta Clearwater River, July - August 1998.

				Recapture rate (R/M)				Capture probability (R/C)			
Events[a]	M[b]	C[c]	R[d]	R/M	SE[R/M	χ^2	p	R/C	SE[R/C]	χ^2	p
Recaptured by all gear types											
Jig marks:											
1 & 2	397	780	38	0.10	0.01			0.05	0.01		
Fly marks:						6.16	0.01			4.85	0.03
1 & 2	382	780	59	0.15	0.02			0.08	0.01		
Jig marks:											
1 & 3	397	716	50	0.13	0.02			0.07	0.01		
Fly marks:						0.28	0.60			0.09	0.76
1 & 3	382	716	53	0.14	0.02			0.07	0.01		
Recaptured by jigs											
Jig marks:											
1 & 2	397	330	20	0.05	0.01			0.06	0.01		
Fly marks						1.42	0.23			1.12	0.29
1 & 2	382	330	27	0.07	0.01			0.08	0.02		
Jig marks:											
1 & 3	397	248	17	0.04	0.01			0.07	0.02		
Fly marks						0.41	0.52			0.57	0.45
1 & 3	382	248	13	0.03	0.01			0.05	0.01		
Recaptured by flies											
Jig marks:											
1 & 2	397	412	17	0.04	0.01			0.04	0.01		
Fly marks						5.54	0.02			4.88	0.03
1 & 2	382	412	32	0.08	0.01			0.08	0.01		
Jig marks:											
1 & 3	397	448	30	0.08	0.01			0.07	0.01		
Fly marks						0.41	0.52			0.57	0.45
1 & 3	382	448	35	0.09	0.01			0.08	0.01		

[a] Events = Event 1: 13 - 17 July; Event 2: 20 - 24 July; Event 3: 10 - 14 August.

[b] M = number of marked fish released alive in first designated event.

[c] C = number of fish examined in second designated event.

[d] R = number of marked fish from first event and recaptured in second designated event.

While capture probabilities of fly and jig marked fish differed, movements and length compositions of the two groups were quite similar. There was no detected difference between fly and jig fish movements 7-d ($\chi^2 = 1.60$; df = 2; P = 0.45) and 21-d after release ($\chi^2 = 1.49$; df = 2; P = 0.48; Table 5). Length compositions of fly- and jig-marked fish were similar in the first event (2 sample Kolmogorov-Smirnov (K-S) test, D = 0.07; P = 0.30) and in the second event (D = 0.06; P = 0.42; Figure 3).

ABUNDANCE

Abundance was estimated with two 5-d events within a two-week period. The hiatus between events on any river mile averaged 7 days. During the first event, 13-17 July, 867 fish ≥150 mm FL were captured of which 17 fish were caught twice, five fish died, and 845 unique fish were released alive with marks (Table 2). During the second event, 20-24 July, 821 fish ≥150 mm FL were captured with 21 fish caught twice, one fish killed and 105 fish recaptured from the first event (Table 2). Since the smallest recaptured fish was 240 mm FL, the data set for estimating abundance was truncated to fish ≥ 240 mm (Table 2). Fish less than 240 mm FL (n = 51) accounted for only 3% of the unique catch from the two events.

The data set was further truncated to eliminate the bias found in capture probabilities between jig and fly marked fish. With jig marked fish less likely to be recaptured than fly caught fish, only fish caught with flies were included in the mark (first) event. Furthermore, all recaptures of fish marked with jigs, spinners, and unknown gear were eliminated from the recapture (second) event. This resulted in a release of 382 marked fish, a catch of 735 fish, and 59 recaptures (Table 7).

Size stratification was not necessary in the experiment since length composition was not significantly different between fish released in the first event and those fish recaptured from the first event (K-S test D = 0.17 and P = 0.10; Figure 4). Tests of consistency by area, however, indicated that there was unequal mixing of fish, unequal catchability of fish, and non-uniform sampling during both events (Table 6). Significant differences were found among the three areas in recapture to examine (R/C) ratios ($\chi^2 = 7.1$; df = 2; P = 0.03), recapture rates (R/M) ($\chi^2 = 13.5$; df = 2; P < 0.01) and movement ($\chi^2 = 83.9$; df = 6; P < 0.01). For this reason, the maximum likelihood (ML) estimates of the stratified model of Darroch (1961) were more appropriate for estimating abundance than the Petersen estimator (Appendix D). The Darroch estimate from fly caught marks was 5570 (SE = 780). From the first event, 432 fish were caught with jigs. The estimated abundance of Arctic grayling ≥ 240 mm in the lower 14 mi of the Delta Clearwater River was 6000 (SE = 780; Table 7). Abundance for fish ≥ 270 mm FL was 4,743 fish (SE = 479; Table 8) and for fish age-5 and older was 4,495 fish (SE = 625; Table 9).

SIZE AND AGE COMPOSITION

The length of fish caught in each of the three events ranged from 165 mm FL to 468 mm FL (Figure 4). The length composition of fish ≥ 150 mm FL captured in the first two events were similar (D = 0.04 and P = 0.66; Figure 5). However, fish caught in the third event were significantly different from the first event (D = 0.11; P < 0.01) and the second event (D = 0.10; P < 0.01; Figure 5) because of fewer small fish. The majority of fish in each event (84% - 94%) was greater than 270 mm FL. The length compositions of fish ≥ 270 mm FL, however, were similar in all three events (Figure 6).

Table 5.-Miles and directions moved by Arctic grayling ≥240 mm FL by gear type that were recaptured seven and 21 days after marking in the Delta Clearwater River, 1998.

	All			Fly			Jig		
	n	p	SE	n	p	SE	n	p	SE
7 Days post release:									
Miles Moved									
>-5		0.07	0.02	4	0.07	0.03	3	0.07	0.04
-2 - -5		0.05	0.02	1	0.02	0.02	3	0.07	0.04
-1 - -2		0.24	0.04	16	0.27	0.06	9	0.21	0.06
0		0.58	0.05	36	0.61	0.06	24	0.56	0.08
1 - 2		0.04	0.02	2	0.03	0.02	2	0.05	0.03
2 - 5		0.01	0.01	0	0	0	1	0.02	0.02
> 5		0.01	0.01	0	0	0	1	0.02	0.02
Total		1.00	---	59	1.00	---	43	1.00	---
Direction Moved[a]									
DS		0.36	0.05	21	0.36	0.06	15	0.35	0.07
NM		0.58	0.05	36	0.61	0.06	24	0.56	0.08
US		0.06	0.02	2	0.03	0.02	4	0.09	0.04
Total		1.00	---	59	1.00	---	43	1.00	---
21-28 Days post release:									
Miles Moved									
>-5	21	0.11	0.02	7	0.07	0.03	13	0.15	0.04
-2 - -5	13	0.07	0.02	6	0.06	0.02	5	0.06	0.03
-1 - -2	22	0.11	0.02	14	0.14	0.03	7	0.08	0.03
0	92	0.48	0.04	52	0.52	0.05	37	0.44	0.05
1 - 2	29	0.15	0.03	10	0.10	0.03	18	0.21	0.04
2 - 5	13	0.07	0.02	10	0.10	0.03	3	0.04	0.02
> 5	3	0.02	0.01	1	0.01	0.01	2	0.02	0.02
Total	193	1.00	---	100	1.00	---	85	1.00	---
Direction Moved[a]									
DS	56	0.29	0.03	27	0.27	0.04	25	0.29	0.05
NM	92	0.48	0.04	52	0.52	0.05	37	0.44	0.05
US	45	0.23	0.03	21	0.21	0.04	23	0.27	0.05
Total	193	1.00	---	100	1.00	---	85	1.00	---

a. Direction moved: DS = downstream; NM = no movement; US = upstream.

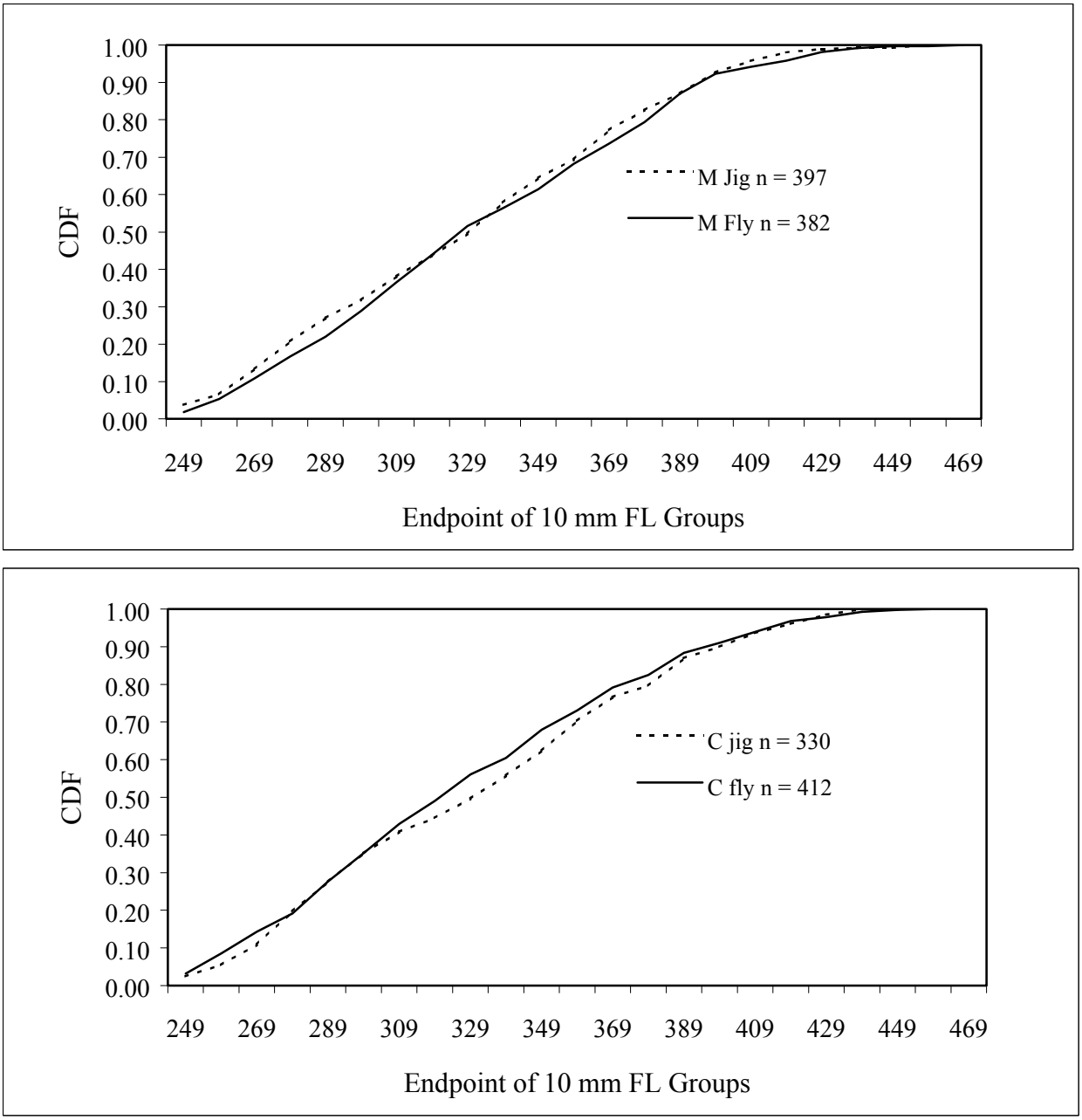

Figure 3.-Cumulative distribution functions (CDF) of 10 mm fork length groups of Arctic grayling ≥ 240 mm FL captured by flies and jigs during the first (M) and second (C) events in the Delta Clearwater River, 13 through 23 July 1998.

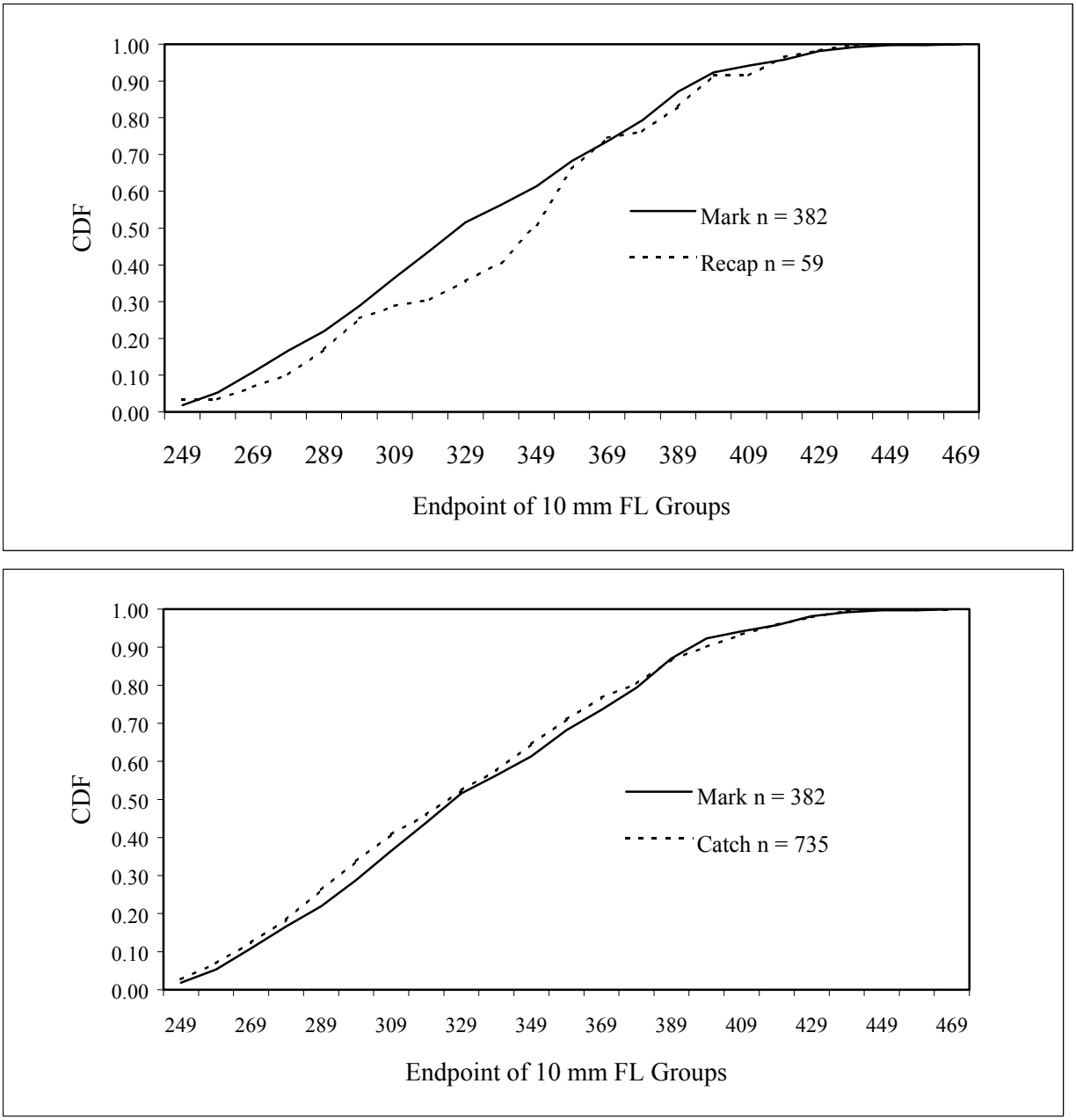

Figure 4.-Cumulative distribution functions (CDF) of 10 mm fork length groups of Arctic grayling ≥ 240 mm FL marked, captured, and recaptured in the Delta Clearwater River, 13 through 23 July 1998.

Table 6.-Capture probability, recapture rate and movement of 59 recaptured Arctic grayling ≥240 mm FL in the Delta Clearwater River 1998 mark-recapture experiment.

Mark Location	Marks	Recapture Location			R/M[a]
		Lower	Middle	Upper	
Lower	56	8	0	0	0.14
Middle	153	1	11	0	0.08
Upper	173	3	1	35	0.23
Total	382	12	12	35	0.10
Examined without marks=		200	196	280	
R/C[b=]		0.06	0.06	0.11	

[a] R/M = recapture rate, number of recaptures divided by number of marked fish released in the first event.

[b] R/C = capture probability, number of recaptures divided by number of fish examined in second event.

Table 7.-Number of fish marked, examined, and recaptured and estimated abundance, standard error and coefficient of variation for Arctic grayling (≥240 mm FL) in three sections of the Delta Clearwater River in 1998.

Section	River miles	Mark	Catch	Recap	N[a]	SE[N]	CV
Lower	2 – 5	56	212	12	1,796	485	27%
Middle	6 – 10	153	208	12	2,560	611	24%
Upper	11 - 14	173	315	35	1,215	62	5%
Total	2 - 14	382	735	59	5,570	782	14%

[a] N estimated with the stratified model of Darroch (1961) based on fly caught marks.

Table 8.-Relative Stock Density (RSD) indices of captured Arctic grayling ≥150 mm FL with abundance and standard errors for fish ≥ 240 mm FL, Delta Clearwater River, July and August 1998.

Category	Length (mm FL)	n	RSD	SE[RSD	N	SE[N]
		July				
Stock	150 - 269	240 (192)[a]	0.16	0.01	---	---
Quality	270 - 339	678	0.46	0.01	2,730	360
Preferred	340 - 449	614	0.41	0.01	2,470	330
Memorable	450 – 559	5	<0.01	<0.01	20	9
Trophy	≥560	0	---	---	---	---
Total		1,537 (1,489)	1.00	---	(6,000)	(780)
Quality+	≥270	1,297	0.87	0.01	4,743	479
		August				
Stock	150 – 269	47 (37)	0.06	0.01	---	---
Quality	270 – 339	359	0.50	0.02	---	---
Preferred	340 – 449	316	0.44	0.02	---	---
Memorable	450 – 559	2	<0.01	<0.01	---	---
Trophy	≥560	0	---	---	---	---
Total		724 (714)	1.00	---	---	---
Quality+	≥270	677	0.94	0.01	---	---

[a] (x) represents only fish ≥ 240 mm FL

Table 9.-Estimates of age composition and abundance by age class with standard errors and coefficient of variation (CV) for Arctic grayling (≥ 240 mm FL), Delta Clearwater River, July 1998.

	Age Composition			Abundance		
Age Class	n	p'[a]	SE[p']	N	SE[N]	CV
3	18	0.04	0.01	213	61	39%
4	89	0.16	0.02	947	170	18%
5	188	0.32	0.02	1,950	300	16%
6	85	0.13	0.01	799	140	17%
7	94	0.14	0.01	814	120	15%
8	72	0.10	0.01	626	110	18%
9	30	0.05	0.01	290	69	24%
10	17	0.03	0.01	152	44	29%
11	15	0.02	0.01	111	33	30%
12	7	0.01	<0.01	39	15	38%
13	6	0.01	<0.01	55	25	46%
14	1	<0.01	<0.01	6	6	100%
Total	607	1.00	---	6,003	782	14%
5+	505	0.81	0.01	4,495	625	14%

[a] p' = estimated adjusted proportion of Arctic grayling at age in the population, weighted by geographic strata.

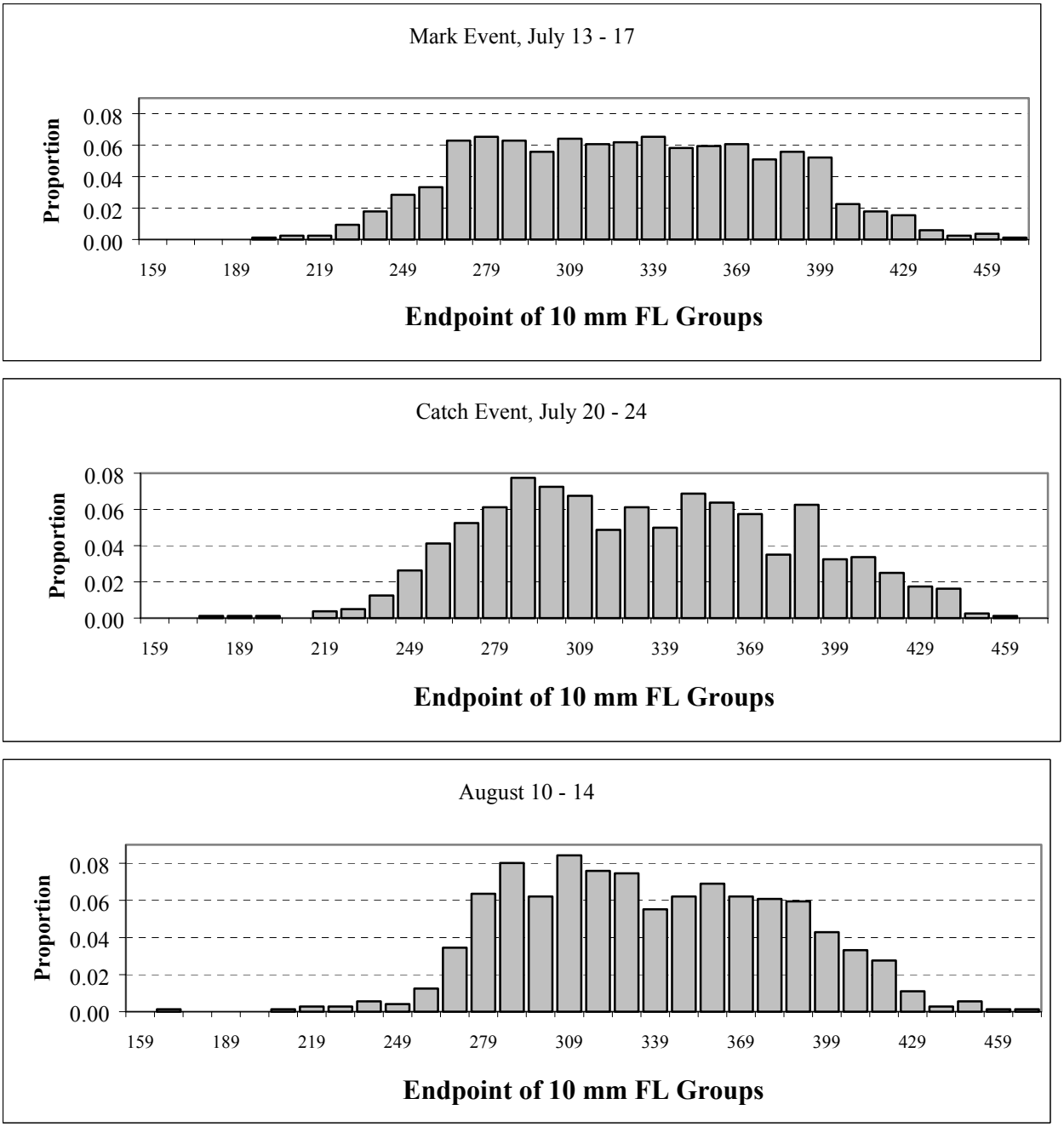

Figure 5.-Length frequency of Arctic grayling (≥150 mm FL) captured in three sampling events, Delta Clearwater River, 1998.

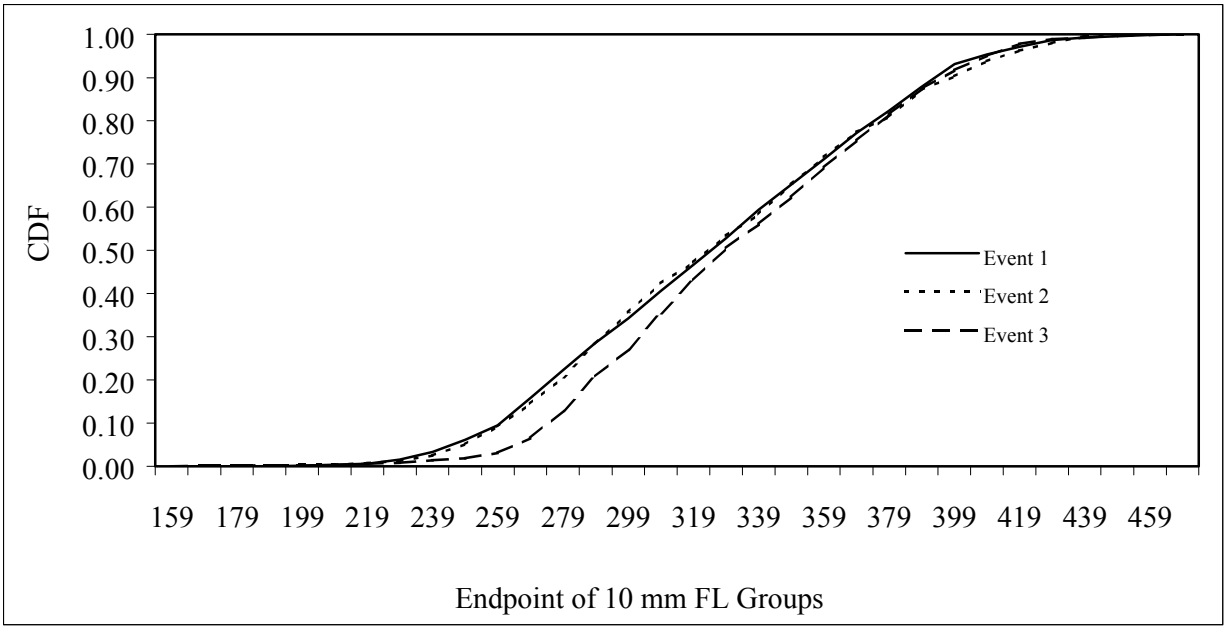

Figure 6.-Cumulative distribution function (CDF) of 10 mm fork length groups of Arctic grayling ≥ 150 mm FL captured in three sampling events in the Delta Clearwater River, 13 - 17 July, 20 - 24 July, and 10 - 14 August 1998.

Size composition of the July population (fish ≥ 240 mm) was estimated from pooled samples of all gear types from the first two events. Size selectivity was not detected in the second event (D = 0.14; P = 0.07) and size composition was similar between events (D = 0.03; P = 0.66) for all gear types combined. In further support of pooling all gear types, size compositions of fly and jig marked fish were similar in the first event (D = 0.07; P = 0.30) and in the second event (D = 0.06; P = 0.42; Figure 3).

RSD estimates of the July abundance were biased by the truncation of the sample to fish ≥ 240 mm. This excluded the majority of the stock sized category (150-269 mm FL). However, abundance was estimated for four of the five RSD categories. Estimated abundance of quality sized and larger fish (≥ 270 mm FL) was 4,743 (SE = 479; Table 8). The July catch contained few stock-sized fish and similar numbers of fish in the quality (270-339 mm) and preferred (340-449 mm) categories (Table 8). There was a smaller proportion of stock-sized fish in the August sample compared to the July sample but a similar proportion of quality and preferred fish (Table 8).

Age composition was estimated from samples taken during the first event. Ages ranged from age-2 to age-14 in the total sample (Appendix A8) and from age-3 to age-14 in the sample ≥ 240 mm FL (Table 9). Age-5 fish were represented at the greatest proportion (30%; SE = 2%) of both samples. The estimated population contained nearly all age-5 fish sampled (188 of 189 age-5 fish were ≥240 mm FL).

MOVEMENTS

Forty-three fish (42%) of 103 recaptured fish, with known release and recapture locations, moved outside of the one-mile sampling areas in which marked during the 7-d hiatus between the first two events (Tables 5 and 10). Eighty-six percent of these fish (n = 37) moved downstream. In the 21-d between the second and third events, 101 fish (52%) of 193 recaptured fish that were initially marked in the second event moved outside of the one-mile sampling areas in which they were marked (Tables 5 and 10). Fifty-five percent of these fish moved upstream (n = 56). These movement patterns were significantly different ($\chi^2 = 14.41$; df = 2; $P < 0.01$; Table 5) between events.

DISCUSSION

This study represents the third consecutive year in which sufficient numbers of Arctic grayling were marked and examined for marks to successfully conduct mark-recapture experiments. Large catches have been unusual in past mid-summer DCR assessment studies where harvest sampling, electrofishing, trapping, or seining all yielded smaller sample sizes. This success was a result of using hook-and-line methods and large sampling crews. The probability of catching a fish in the DCR depends on many variables that cannot be held constant over the course of a study. Catches are influenced by angling ability, the choice of terminal gear, the location fished, the time of day, the depth of the fish and whether the fish is feeding. These concerns were addressed over the past three years by soliciting experienced anglers, spreading daily effort throughout the river, mixing crew assignments, and applying the majority of effort during the time of day when fish were most actively feeding.

Table 10.-Movement matrix for Arctic grayling ≥240 mm FL recaptured seven and 21 days after marking in the Delta Clearwater River, July 1998. Study sections are depicted with borders.

	Mile at Recapture														
Mile at Mark	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
7 Days post release															
2	6		1							1					8
3		1													1
4	6		3	1		1									11
5	1		2	3											6
6					4										4
7					2	3									5
8				1	1	1	1								4
9				1				3							4
10						1			3						4
11		1						1		6					8
12		1		1	1						8				11
13			1							1	6	11	2		21
14		2								1	3	2	8		16
15															nm[a]
Total	13	5	7	7	8	6	1	4	3	9	17	13	10	nm	103
21 Days post release															
2		1	5					1							7
3		4													4
4		1	18	1	2							1			23
5			1	3	1										5
6			2	1	5	3		1		4	1				17
7		1	2			8	1		2						14
8			1			1	6				1				9
9		1		1			1	8		1	1	1			14
10					1				3	3	1			1	9
11			3	3			1		1	11	1		1	1	22
12			1		3					5	5				14
13		1	2		1		2	1	1		7	3	3	2	23
14		2	1			1	2	1	1		2		18	4	32
15															nm
Total	0	11	36	9	13	13	13	12	8	24	19	5	22	8	193

[a] nm = No marked fish were released in Mile 15. The mile was not sampled in the first and second event.

Hook shyness in the 1998 experiment was not directly measured but relative differences between fly- and jig-marked fish were inferred from differences in recapture rates. There is a distinct difference between flies and jigs in appearance, use, and the manner in which Arctic grayling take each type. The lower recapture rate of jig-marked fish may be explained by shyness from the gear that initially caught them or perhaps more likely due to a combination of fish behavior, location, and the efficiency of the gear and angler. When Arctic grayling are not feeding, jigs are more effective in catching fish because of the fish's aggressive behavior towards the jig and the ability of anglers to get jigs down to fish holding in deep water. Flies are more effective when fish are actively feeding or in shallower water. It is unclear whether the difference in catchability was due to hook shyness alone, a change in behavior, or a combination of events. Nonetheless, the recapture rate of jig-marked fish was lower than fly-marked fish.

Biased estimates result when the marking of fish affects the probability of capture in the second event. To reduce this type of bias, stratification or truncating the data set, is necessary. Since considerably lower jig-marked fish were released in 1996 and 1997 than in 1998, the gear bias detected in this study may not affect the estimates of abundance obtained for 1996 and 1997. Gear type, however, was not recorded in these years so the affect of gear bias, although probably minimal, can not be examined (Appendix A13). In this study, where a similar number of jig- and fly-marks were released, estimated abundance would have been greater by approximately 430 fish by including jig marks from the experiment (Appendix C), or an estimated bias of 8%. This bias could increase substantially if a higher proportion of jig-marked fish are released during the marking event.

Based on data from this study, different combinations of jig and fly caught fish in either event would have resulted in bias as high as 42%. Using the 1998 data for fish ≥ 240 mm to calculate an estimate of abundance without adjusting for bias, estimated bias would have ranged from -15% to 42% from the 1998 estimate of abundance (5,570 fish):

Gear at M	Gear at C	M	C	R	N	SE[N]	Bias
All	All	818	780	105	5,997	539	8%
Fly	Fly	378	412	32	4,731	778	-15%
Fly	All	378	780	59	4,920	612	-12%
Jig	Jig	396	330	20	6,242	1,288	21%
Jig	All	396	780	38	7,930	1,222	42%

Even though this bias probably did not affect the estimates of abundance from prior years, future experiments should either refrain from using jigs in the mark event, lengthen the hiatus between events (no significant differences in capture probability between flies and jigs were found after a 21-d hiatus; Tables 3 and 4), or go to a multi-year estimator. However, recapture rates should also be investigated again in 1999 to determine if the difference in capture probability between jig and fly marked fish is consistent and not merely unique to 1998. Type of capture gear should be recorded for each captured fish and gear bias investigated in all hook-and-line mark-recapture experiments.

There was conspicuous movement of marked fish during the July mark-recapture experiment. Approximately 50% of marked fish moved from the one-mile sampling area to another area. If this movement was specific to marked fish only and resulted in emigrating from the study area, the estimate of abundance would be biased high. Movement was predominantly downstream

which suggests that these fish either reacted to handling stress or simply exhibited normal movements along with unmarked fish. Emigration out of the study area, however, is considered unlikely for either group because the experiment was in the mid-summer feeding period and feeding was the reason fish immigrated the river. Furthermore, the lower boundary of the study area is a distinct habitat transition, silt laden and inhospitable to feeding.

Similar proportions of fish moved between the July experiment and the August sample but exhibited significantly different patterns. By August, fish had moved equally up and downstream from areas of release. While handling stress may have contributed to the movements during the abundance experiment, fish may have simply been using the whole river as a feeding area rather than a specific location. There were similar movement patterns of jig and fly marked fish in both the July and August samples. This suggests that the different capture probabilities for jig-marked and fly-marked fish may not have been due to handling stress. If handling stress were the cause, different movement patterns would probably occur, but was not found. Anecdotal evidence from experienced anglers, that have fished the Delta and Richardson Clearwater rivers, reported intermittent absences of fish in upper reaches of these rivers throughout the season. Even though this study did not find evidence of fewer fish in the upper section during the second event, the sizable catch and recaptures of marked fish in river mi 15 in the August sample supports seasonal intra-stream movements. This movement during the summer feeding period infers that regulations designed to offer a sanctuary for a portion of the DCR population while offering a consumptive fishery may not protect that portion of the population. Studies of in-season movements of Arctic grayling in spring-fed systems should be undertaken if sanctuaries are included in management plans.

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APPENDIX A

Data Summaries

Appendix A1.-Summary of Arctic grayling stocked into the Delta Clearwater River, 1974 through 1987.

Year	Brood	Rearing Location	Date	Number	Location	Age	Fish/lb	Weight	Length	Mark	Number
1974	Moose	Hatchery	14-Jun	300,000	Cl Lake	fry	---	---	---	no	---
1975	Moose	Hatchery	26-Jun	100,000	DCR springs	fry	---	---	---	no	---
1975	Moose	ponds	2-Oct	9,100	DCR springs	yearlings	35	---	---	no	---
1976	Moose	ponds	20-Sep	12,096	DCR springs	yearlings	40	---	104	no	---
1977	Moose	ponds	28-Sep	6,684	DCR springs	yearlings	38	---	109	no	---
1977	Moose	ponds	28-Sep	371	DCR	1+	3.6	---	---	no	---
1978	Moose	ponds	21-Sep	6,558	DCR springs	yearlings	33	---	117	no	---
1979	Moose	ponds	26-Sep	651	DCR	1+	2.6	---	247	tag	all
1983	Jack	Hatchery	31-Aug	2,503	DCR springs	yearlings	194	2.3	60	RP	all
1983	Jack	Hatchery	30-Sep	2,983	DCR springs	yearlings	82	5.5	86	RV	all
1983	Moose	ponds	26-Aug	2,189	DCR springs	yearlings	40	11.4	108	Ad/LV	all
1983	Moose	ponds	23-Sep	3,292	DCR springs	yearlings	18	25.3	120	Ad	all
1984	Moose	ponds	8-Jun	1,009	DCR	1+	---	---	170	tag	all
1984	Moose	ponds	21-Sep	122	DCR	1+	2.3	198	232	tag	all
1984	Jack	Hatchery	26-Sep	17,380	DCR springs	yearlings	209	2.2	62	LV	8,038
1985	Moose	ponds	14-Jun	551	DCR	1+	---	---	172	tag	all
1985	Moose	ponds	3-Oct	638	DCR	1+	---	---	211	tag	all
1985	Goodpaster	ponds	1-Oct	12,744	DCR springs	yearlings	41	11.1	103	LP	all
1985	Goodpaster	Hatchery	20-Sep	20,950	DCR springs	yearlings	97	4.7	76	Ad	10,468
1986	Goodpaster	ponds	29-Aug	4,273	DCR springs	yearlings	---	7.3	88	Ad/LV	all
1986	Goodpaster	Hatchery	27-Aug	5,748	DCR springs	yearlings	---	3.7	76	LV	all
1986	Goodpaster	ponds	26-Sep	6,940	DCR springs	yearlings	---	---	---	Ad/RP	all
1986	Goodpaster	ponds	3-Oct	2,928	DCR springs	yearlings	---	---	---	Ad/RP	all

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Year	Brood	Rearing Location	Date	Number	Location	Age	Fish/lb	Weight	Length	Mark	Number
1986	Goodpaster	Hatchery	24-Sep	6,016	DCR springs	yearlings	---	7.5	90	RP	all
1987	Goodpaster	ponds	4-Sep	1,310	DCR springs	yearlings	---	---	---	Ad/RV	all
1987	Goodpaster	ponds	4-Sep	35	DCR	1+	---	---	---	tag	all
1987	Goodpaster	Hatchery	28-Aug	5,040	DCR springs	yearlings	105	12.1		RV	all
1987	Goodpaster	ponds	3-Oct	3,442	DCR springs	yearlings	---	---	---	Ad/LV	all
1987	Goodpaster	ponds	3-Oct	54	DCR	1+	---	---	---	tag	all
1987	Goodpaster	Hatchery	7-Oct	5,010	DCR springs	yearlings	77	4	---	LV	all
					Totals						
				400,000		fry					
				164,355		yearlings					
				3,431		1+					
				567,786		Total					

Appendix A2.-Summary of effort, catch, and catch per unit effort (number of Arctic grayling caught per angler-hour) for the mark-recapture experiment in the Delta Clearwater River 1998 by river mile and event.

Section	River mi	Angler-days	Angler-hrs	Catch	CPUE
		Mark Event, July 13 – 17			
Upstream	14	4	28	148	5.3
	13	4	25	89	3.6
	12	5	37	64	1.7
	11	2	10	36	3.6
	10	4	25	40	1.6
	9	2	16	46	2.9
Subtotal	---	21	141	423	3.0
Downstream	8	4	23	69	3.0
	7	3	24	54	2.3
	6	3	21	83	4.0
	5	3	16	56	3.5
	4	2	13	48	3.5
	3	2	13	37	2.8
	2	2	13	97	7.5
Subtotal	---	19	123	444	3.6
Mark Total	---	40	264	867	3.3
		Catch Event, July 20 - 24:			
Upstream	14	2	15	52	3.5
	13	4	24	102	4.3
	12	5	33	97	2.9
	11	3	17	95	5.6
	10	2	13	31	2.4
	9	3	20	65	3.3
Subtotal	---	19	122	442	3.6
Downstream	8	3	15	41	2.7
	7	2	12	51	4.3
	6	2	11	48	4.4
	5	4	28	51	1.8
	4	2	14	58	4.1
	3	2	13	50	3.8
	2	2	12	80	6.7
Subtotal	---	17	105	379	3.6
Catch Total	---	36	227	821	3.6
Total for Experiment	---	76	491	1,688	3.4

Appendix A3.-Summary of effort, catch, and catch per unit effort (number of Arctic grayling caught per angler-hour) for the third event in the Delta Clearwater River August 1998 by river mile.

Section	River mi	Angler-days	Angler-hrs	Catch	CPUE
Upstream	15	2	13	43	3.3
	14	2	15	74	4.9
	13	3	19	33	1.7
	12	2	14	48	3.4
	11	2	13	65	5.0
	10	2	12	31	2.6
	9	2	13	59	4.5
Subtotal		15	99	353	3.6
Downstream	8	2	13	57	4.4
	7	2	12	34	2.8
	6	2	12	41	3.4
	5	2	13	43	3.3
	4	4	27	133	4.9
	3	2	13	56	4.3
	2	2	10	38	3.8
Subtotal		16	100	402	4.0
Total		31	199	755	3.8

Appendix A4.-Individual effort, catch, and catch per unit effort (number of Arctic grayling (≥ 150 mm FL) caught per angler-hour) during the mark-recapture experiment in the Delta Clearwater River 13 – 24 July 1998.

Angler	Hours	Catch	CPUE
1	66	492	7.45
2	26	132	5.18
3	33	156	4.76
4	13	59	4.54
5	44	172	3.93
6	7	27	3.86
7	8	28	3.61
8	19	66	3.57
9	13	46	3.54
10	8	26	3.35
11	14	44	3.26
12	13	39	3.12
13	2	5	2.50
14	5	12	2.40
15	51	119	2.34
16	7	14	2.15
17	7	14	2.00
18	33	62	1.91
19	17	32	1.88
20	4	7	1.75
21	14	23	1.64
22	26	42	1.60
23	7	11	1.57
24	5	7	1.56
25	7	9	1.38
26	14	17	1.24
27	7	7	1.00
28	8	4	0.53
29	7	3	0.43
30	7	3	0.43
Total	486	1,678	3.45
Average	16	56	2.62
Median	10	27	2.25

Appendix A5.-Individual effort, catch, and catch per unit effort (number of Arctic grayling caught per angler-hour) in the Delta Clearwater River 10 - 14 August 1998.

Angler	Hours	Catch	CPUE
1	20	132	6.52
2	7	34	5.23
3	25	116	4.64
4	13	59	4.45
5	26	114	4.43
6	7	23	3.54
7	7	22	3.38
8	7	21	3.23
9	32	101	3.21
10	12	36	3.13
11	19	46	2.49
12	8	16	2.13
13	7	13	2.00
14	6	11	1.91
15	7	8	1.23
Total	198	752	3.80
Average	13	50	3.43
Median	8	34	3.31

Appendix A6.-Summary of Arctic grayling ≥240 mm FL caught and recaptured by three gear types in the Delta Clearwater River, 1998.

				Recaptures of C_{1i} in C_2 by:					Recaptures of C_{1i} in C_3 by:					Recaptures of C_{2i} in C_3 by:				
" i "	C_{1i}[a]	C_{2i}	C_{3i}	Total	Jig	Fly	Spinner	Unk	Total	Jig	Fly	Spinner	Unk	Total	Jig	Fly	Spinner	Unk
Jig	397	330	248	38	20	17	1	0	50	17	30	0	3	32	13	18	0	1
Fly	382	412	448	59	27	32	0	0	52	13	35	0	4	55	10	43	0	2
Spinner	30	2	0	5	3	2	0	0	4	1	2	0	1	0	0	0	0	0
Unk	9	36	20	3	1	2	0	0	5	2	3	0	0	4	3	1	0	0
Total	818	780	716	105	51	53	1	0	111	33	70	0	8	91	26	62	0	3

[a] C_{xi} = Catch in event x by gear type i.

Appendix A7.-Distribution of captured Arctic grayling ≥240 mm FL by gear type and river mile in the Delta Clearwater River, 1998.

	Event 1					Event 2					Event 3			
River Mile	Unk[a]	Spinner	Fly	Jig	Total	Unk	Spinner	Fly	Jig	Total	Unk	Fly	Jig	Total
2	0	0	1	81	82	0	0	1	78	79	0	3	33	36
3	0	30	5	0	35	0	0	0	46	46	0	19	37	56
4	0	0	30	17	47	1	0	38	18	57	0	102	19	121
5	3	0	20	27	50	0	0	15	35	50	0	20	22	42
6	1	0	43	35	79	0	0	38	9	47	16	15	9	40
7	0	0	15	36	51	0	0	34	14	48	0	24	8	32
8	0	0	40	22	62	6	0	27	0	33	0	48	2	50
9	0	0	22	20	42	1	1	51	6	59	0	30	28	58
10	0	0	33	6	39	0	0	10	21	31	0	23	7	30
11	1	0	20	14	35	0	0	80	10	90	0	53	7	60
12	0	0	29	33	62	0	1	69	20	90	3	27	13	43
13	0	0	81	5	86	28	0	33	39	100	0	20	12	32
14	4	0	43	101	148	0	0	16	34	50	0	53	20	73
15	0	0	0	0	0	0	0	0	0	0	1	11	31	43
Total	9	30	382	397	818	36	2	412	330	780	20	448	248	716

[a] unk = unknown gear type.

Appendix A8.-Estimates of age composition and mean length at age for all Arctic grayling captured by hook and line in the Delta Clearwater River, 13-17 July 1998.

	Age Composition			Length (mm FL)			
Age Class	n	p	SE[p]	mean	std	min	max
2	1	0.00	0.00	196	---	196	196
3	29	0.05	0.01	250	22	209	286
4	93	0.15	0.01	274	23	205	351
5	189	0.30	0.02	304	28	239	379
6	85	0.13	0.01	328	39	250	415
7	94	0.15	0.01	358	32	268	443
8	72	0.11	0.01	369	26	293	422
9	30	0.05	0.01	378	29	308	444
10	17	0.03	0.01	379	29	331	423
11	15	0.02	0.01	395	25	352	435
12	7	0.01	0.00	412	10	395	428
13	6	0.01	0.00	422	27	382	452
14	1	0.00	0.00	406	---	406	406
Totals	639	1.00	---	328	50	196	452

Appendix A9.-Estimates of age composition and mean length at age for all Arctic grayling captured by hook and line in the Delta Clearwater River, 19-31 July 1996.

	Age Composition			Length (mm FL)			
Age Class	n	p	SE[p]	mean	std	min	max
1	1	0.00	0.00	134	---	134	134
2	5	0.01	0.00	191	16	174	210
3	72	0.12	0.01	247	20	208	300
4	51	0.09	0.01	283	20	243	323
5	124	0.21	0.02	313	23	246	382
6	147	0.25	0.02	339	23	291	402
7	87	0.15	0.01	366	23	310	410
8	36	0.06	0.01	382	23	326	426
9	40	0.07	0.01	397	18	354	428
10	15	0.03	0.01	401	19	373	438
11	8	0.01	0.00	421	14	399	439
12	5	0.01	0.00	426	28	391	464
Total	591	1.00	---	334	52	134	464

Appendix A10.-Estimates of age composition and mean length at age for all Arctic grayling captured by hook and line in the Delta Clearwater River, 21-25 July 1997.

	Age Composition			Length (mm FL)			
Age Class	n	p	SE[p]	mean	std	min	max
1	2	0.00	0.00	146	6	142	150
2	46	0.06	0.01	184	10	158	204
3	109	0.15	0.01	230	18	190	293
4	195	0.27	0.02	279	22	224	353
5	64	0.09	0.01	317	27	259	372
6	139	0.19	0.01	343	22	290	405
7	71	0.10	0.01	358	22	310	405
8	48	0.07	0.01	373	26	312	419
9	21	0.03	0.01	393	24	348	443
10	12	0.02	0.00	399	25	354	445
11	7	0.01	0.00	395	46	304	462
12	1	0.00	0.00	434	---	434	434
13	2	0.00	0.00	431	25	413	449
Totals	717	1.00	---	306	63	142	462

Appendix A11.-Relative Stock Density (RSD) indices of Arctic grayling (≥ 150 mm FL) captured during mark-recapture experiments in the Delta Clearwater River, July 1996 - 1998.

Category	Length (mm FL)	n	RSD	SE[RSD]
		1996		
Stock	150 - 269	96	0.12	0.01
Quality	270 - 339	328	0.41	0.02
Preferred	340 - 449	372	0.47	0.02
Memorable	450 - 559	1	<0.01	<0.01
Trophy	≥560	0	---	---
Total		797	1.00	---
		1997		
Stock	150 - 269	347	0.24	0.01
Quality	270 - 339	557	0.39	0.01
Preferred	340 - 449	528	0.37	0.01
Memorable	450 - 559	1	<0.01	<0.01
Trophy	≥560	0	---	---
Total		1,433	1.00	---
		1998		
Stock	150 - 269	240	0.16	0.01
Quality	270 - 339	681	0.44	0.01
Preferred	340 - 449	616	0.40	0.01
Memorable	450 - 559	5	<0.01	<0.01
Trophy	≥560	0	---	---
Total		1,542	1.00	---

Appendix A12.-Date, location, length and, gear type at release and at recapture of Arctic grayling in the Delta Clearwater River, 1998.

Date	Recapture Date		River Mile			Length (mm FL)			Gear Type		
of release	Event 2	Event 3	Release	Event 2	Event 3	Release	Event 2	Event 3	Release	Event 2	Event 3
13-Jul	20-Jul	10-Aug	6	6	6	360	364	368	fly	fly	jig
13-Jul	20-Jul	---	10	10	---	396	396	---	fly	fly	---
13-Jul	20-Jul	---	8	6	---	288	287	---	fly	fly	---
13-Jul	20-Jul	---	6	6	---	273	277	---	fly	fly	---
13-Jul	20-Jul	---	10	10	---	334	331	---	fly	jig	---
13-Jul	20-Jul	---	10	10	---	383	381	---	fly	jig	---
14-Jul	20-Jul	---	13	4	---	415	418	---	fly	jig	---
15-Jul	20-Jul	---	7	6	---	294	298	---	fly	fly	---
15-Jul	20-Jul	---	5	4	---	279	276	---	fly	jig	---
16-Jul	20-Jul	---	12	6	---	395	396	---	fly	jig	---
13-Jul	21-Jul	---	12	12	---	353	353	---	fly	jig	---
14-Jul	21-Jul	---	13	13	---	362	360	---	fly	fly	---
14-Jul	21-Jul	---	13	13	---	250	245	---	fly	fly	---
14-Jul	21-Jul	---	13	11	---	254	262	---	fly	fly	---
14-Jul	21-Jul	---	5	5	---	389	389	---	fly	fly	---
14-Jul	21-Jul	---	13	13	---	368	368	---	fly	jig	---
15-Jul	21-Jul	---	11	11	---	355	356	---	fly	fly	---
15-Jul	21-Jul	---	11	11	---	381	380	---	fly	fly	---
15-Jul	21-Jul	---	9	9	---	331	330	---	fly	fly	---
15-Jul	21-Jul	---	11	11	---	338	344	---	fly	jig	---
15-Jul	21-Jul	---	11	11	---	340	341	---	fly	jig	---
16-Jul	21-Jul	---	13	13	---	356	357	---	fly	jig	---
16-Jul	21-Jul	---	13	12	---	384	383	---	fly	jig	---
13-Jul	22-Jul	10-Aug	12	12	6	325	328	325	fly	fly	unk
13-Jul	22-Jul	---	12	12	---	438	438	---	fly	fly	---
13-Jul	22-Jul	---	12	12	---	297	299	---	fly	fly	---
13-Jul	22-Jul	---	12	12	---	352	358	---	fly	fly	---

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Date	Recapture Date		River Mile			Length (mm FL)			Gear Type		
of release	Event 2	Event 3	Release	Event 2	Event 3	Release	Event 2	Event 3	Release	Event 2	Event 3
13-Jul	22-Jul	---	12	12	---	415	413	---	fly	jig	---
14-Jul	22-Jul	---	13	12	---	300	355	---	fly	fly	---
14-Jul	22-Jul	---	4	2	---	287	290	---	fly	jig	---
14-Jul	22-Jul	---	4	2	---	274	280	---	fly	jig	---
14-Jul	22-Jul	---	4	2	---	254	261	---	fly	jig	---
14-Jul	22-Jul	---	4	2	---	290	291	---	fly	jig	---
15-Jul	22-Jul	---	11	11	---	347	345	---	fly	fly	---
16-Jul	22-Jul	---	13	12	---	349	352	---	fly	fly	---
16-Jul	22-Jul	---	13	12	---	360	362	---	fly	fly	---
16-Jul	22-Jul	---	13	12	---	351	350	---	fly	fly	---
16-Jul	22-Jul	---	13	12	---	363	365	---	fly	fly	---
16-Jul	22-Jul	---	8	8	---	246	248	---	fly	fly	---
13-Jul	23-Jul	---	14	14	---	318	299	---	fly	jig	---
13-Jul	23-Jul	---	14	3	---	330	333	---	fly	jig	---
13-Jul	23-Jul	---	8	7	---	335	344	---	fly	jig	---
14-Jul	23-Jul	---	13	14	---	276	280	---	fly	fly	---
15-Jul	23-Jul	---	7	7	---	320	324	---	fly	fly	---
15-Jul	23-Jul	---	11	3	---	308	309	---	fly	jig	---
16-Jul	23-Jul	---	14	14	---	395	396	---	fly	fly	---
16-Jul	23-Jul	---	14	14	---	342	347	---	fly	jig	---
16-Jul	23-Jul	---	13	14	---	280	281	---	fly	jig	---
13-Jul	24-Jul	---	8	5	---	297	305	---	fly	jig	---
14-Jul	24-Jul	---	5	5	---	422	425	---	fly	jig	---
15-Jul	24-Jul	---	5	5	---	328	320	---	fly	fly	---
16-Jul	24-Jul	12-Aug	13	13	12	411	410	407	fly	fly	jig

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Date	Recapture Date		River Mile			Length (mm FL)			Gear Type		
of release	Event 2	Event 3	Release	Event 2	Event 3	Release	Event 2	Event 3	Release	Event 2	Event 3
16-Jul	24-Jul	---	13	13	---	379	unk	---	fly	fly	---
16-Jul	24-Jul	---	13	13	---	352	354	---	fly	fly	---
16-Jul	24-Jul	---	13	13	---	394	394	---	fly	fly	---
16-Jul	24-Jul	---	13	13	---	312	unk	---	fly	fly	---
16-Jul	24-Jul	---	14	12	---	398	394	---	fly	jig	---
16-Jul	24-Jul	---	13	13	---	347	344	---	fly	jig	---
16-Jul	24-Jul	---	13	13	---	356	354	---	fly	jig	---
13-Jul	---	10-Aug	14	---	14	243	---	264	fly	---	fly
13-Jul	---	10-Aug	14	---	14	386	---	390	fly	---	fly
13-Jul	---	10-Aug	14	---	14	310	---	315	fly	---	fly
13-Jul	---	10-Aug	14	---	14	273	---	282	fly	---	fly
13-Jul	---	10-Aug	14	---	14	346	---	352	fly	---	fly
13-Jul	---	10-Aug	6	---	7	292	---	300	fly	---	fly
13-Jul	---	10-Aug	14	---	14	420	---	425	fly	---	jig
13-Jul	---	10-Aug	6	---	6	292	---	303	fly	---	unk
13-Jul	---	11-Aug	14	---	12	351	---	354	fly	---	fly
13-Jul	---	11-Aug	10	---	11	290	---	295	fly	---	fly
13-Jul	---	11-Aug	6	---	11	385	---	297	fly	---	fly
13-Jul	---	11-Aug	6	---	12	315	---	328	fly	---	fly
13-Jul	---	11-Aug	8	---	12	311	---	317	fly	---	unk
13-Jul	---	12-Aug	10	---	10	443	---	448	fly	---	fly
13-Jul	---	12-Aug	10	---	15	363	---	366	fly	---	fly
13-Jul	---	13-Aug	8	---	8	312	---	312	fly	---	fly
13-Jul	---	13-Aug	6	---	9	273	---	284	fly	---	fly
13-Jul	---	13-Aug	6	---	5	329	---	335	fly	---	jig
13-Jul	---	14-Aug	8	---	4	312	---	320	fly	---	jig
14-Jul	---	10-Aug	13	---	13	314	---	328	fly	---	jig
14-Jul	---	11-Aug	4	---	4	304	---	315	fly	---	fly

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Date	Recapture Date		River Mile			Length (mm FL)			Gear Type		
of release	Event 2	Event 3	Release	Event 2	Event 3	Release	Event 2	Event 3	Release	Event 2	Event 3
14-Jul	---	11-Aug	4	---	3	327	---	330	fly	---	fly
14-Jul	---	12-Aug	4	---	4	310	---	315	fly	---	fly
14-Jul	---	12-Aug	4	---	4	300	---	305	fly	---	fly
14-Jul	---	12-Aug	4	---	4	273	---	280	fly	---	fly
14-Jul	---	13-Aug	13	---	8	392	---	388	fly	---	fly
14-Jul	---	14-Aug	4	---	4	372	---	382	fly	---	fly
15-Jul	---	11-Aug	11	---	11	316	---	321	fly	---	fly
15-Jul	---	11-Aug	9	---	11	250	---	260	fly	---	fly
15-Jul	---	11-Aug	9	---	3	382	---	380	fly	---	jig
15-Jul	---	12-Aug	11	---	15	355	---	355	fly	---	jig
15-Jul	---	13-Aug	9	---	8	380	---	382	fly	---	fly
15-Jul	---	13-Aug	9	---	9	305	---	310	fly	---	fly
15-Jul	---	13-Aug	9	---	5	298	---	300	fly	---	fly
16-Jul	---	10-Aug	14	---	14	255	---	263	fly	---	fly
16-Jul	---	10-Aug	14	---	14	322	---	325	fly	---	jig
16-Jul	---	10-Aug	14	---	14	370	---	374	fly	---	jig
16-Jul	---	10-Aug	8	---	7	414	---	416	fly	---	jig
16-Jul	---	10-Aug	10	---	6	365	---	368	fly	---	unk
16-Jul	---	11-Aug	13	---	12	376	---	376	fly	---	fly
16-Jul	---	11-Aug	13	---	12	296	---	304	fly	---	fly
16-Jul	---	11-Aug	10	---	11	359	---	364	fly	---	fly
16-Jul	---	11-Aug	13	---	4	295	---	299	fly	---	jig
16-Jul	---	11-Aug	13	---	12	303	---	312	fly	---	jig
16-Jul	---	12-Aug	14	---	15	377	---	383	fly	---	fly
16-Jul	---	12-Aug	14	---	10	402	---	399	fly	---	fly
16-Jul	---	12-Aug	10	---	12	296	---	293	fly	---	fly
16-Jul	---	13-Aug	8	---	8	389	---	395	fly	---	fly
17-Jul	---	12-Aug	7	---	4	300	---	300	fly	---	fly

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Date	Recapture Date		River Mile			Length (mm FL)			Gear Type		
of release	Event 2	Event 3	Release	Event 2	Event 3	Release	Event 2	Event 3	Release	Event 2	Event 3
13-Jul	---	10-Aug	14	---	7	385	---	399	jig	---	fly
13-Jul	---	10-Aug	14	---	14	303	---	317	jig	---	fly
13-Jul	---	10-Aug	14	---	14	370	---	379	jig	---	fly
13-Jul	---	10-Aug	14	---	14	308	---	305	jig	---	fly
13-Jul	---	10-Aug	6	---	6	286	---	297	jig	---	fly
13-Jul	---	10-Aug	14	---	14	280	---	300	jig	---	jig
13-Jul	---	10-Aug	14	---	14	335	---	340	jig	---	jig
13-Jul	---	10-Aug	14	---	14	315	---	325	jig	---	jig
13-Jul	---	10-Aug	12	---	6	360	---	362	jig	---	unk
13-Jul	---	11-Aug	12	---	12	297	---	306	jig	---	unk
13-Jul	---	12-Aug	14	---	15	335	---	349	jig	---	jig
13-Jul	---	13-Aug	14	---	8	330	---	340	jig	---	fly
14-Jul	---	10-Aug	4	---	6	288	---	295	jig	---	jig
14-Jul	---	11-Aug	4	---	4	364	---	370	jig	---	fly
14-Jul	---	11-Aug	2	---	4	240	---	240	jig	---	fly
14-Jul	---	12-Aug	2	---	4	280	---	282	jig	---	fly
14-Jul	---	12-Aug	2	---	4	260	---	262	jig	---	fly
14-Jul	---	12-Aug	2	---	4	345	---	350	jig	---	fly
15-Jul	---	10-Aug	6	---	7	262	---	274	jig	---	fly
15-Jul	---	10-Aug	5	---	6	299	---	308	jig	---	unk
15-Jul	---	11-Aug	11	---	11	348	---	350	jig	---	fly
15-Jul	---	11-Aug	6	---	11	298	---	303	jig	---	fly
15-Jul	---	11-Aug	6	---	11	308	---	317	jig	---	fly
15-Jul	---	11-Aug	11	---	11	367	---	366	jig	---	jig
15-Jul	---	12-Aug	6	---	4	302	---	303	jig	---	fly
15-Jul	---	13-Aug	5	---	5	314	---	322	jig	---	fly
15-Jul	---	13-Aug	9	---	9	314	---	308	jig	---	jig
15-Jul	---	13-Aug	9	---	9	368	---	370	jig	---	jig

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Date	Recapture Date		River Mile			Length (mm FL)			Gear Type		
of release	Event 2	Event 3	Release	Event 2	Event 3	Release	Event 2	Event 3	Release	Event 2	Event 3
15-Jul	---	13-Aug	9	---	9	336	---	343	jig	---	jig
16-Jul	---	10-Aug	14	---	14	268	---	285	jig	---	fly
16-Jul	---	11-Aug	14	---	3	368	---	369	jig	---	fly
16-Jul	---	11-Aug	12	---	4	415	---	306	jig	---	fly
16-Jul	---	11-Aug	14	---	3	368	---	360	jig	---	jig
16-Jul	---	11-Aug	14	---	12	365	---	unk	jig	---	jig
16-Jul	---	12-Aug	14	---	15	330	---	330	jig	---	fly
16-Jul	---	12-Aug	13	---	15	283	---	325	jig	---	fly
16-Jul	---	12-Aug	12	---	12	384	---	385	jig	---	fly
16-Jul	---	12-Aug	14	---	15	320	---	320	jig	---	jig
16-Jul	---	13-Aug	14	---	8	358	---	358	jig	---	fly
16-Jul	---	13-Aug	8	---	8	410	---	410	jig	---	fly
16-Jul	---	13-Aug	14	---	9	330	---	336	jig	---	jig
16-Jul	---	13-Aug	11	---	5	284	---	378	jig	---	jig
16-Jul	---	13-Aug	8	---	8	377	---	381	jig	---	jig
17-Jul	---	10-Aug	7	---	7	283	---	291	jig	---	jig
17-Jul	---	11-Aug	7	---	4	293	---	304	jig	---	fly
17-Jul	---	13-Aug	7	---	8	268	---	280	jig	---	fly
14-Jul	20-Jul	11-Aug	4	4	4	301	unk	307	jig	fly	fly
14-Jul	20-Jul	---	5	4	---	346	342	---	jig	fly	---
14-Jul	20-Jul	---	2	4	---	238	240	---	jig	fly	---
15-Jul	20-Jul	---	6	6	---	291	294	---	jig	fly	---
15-Jul	20-Jul	---	6	6	---	300	301	---	jig	fly	---
17-Jul	20-Jul	---	7	6	---	400	405	---	jig	fly	---
15-Jul	21-Jul	11-Aug	11	11	11	413	414	411	jig	fly	fly
15-Jul	21-Jul	---	9	9	---	331	331	---	jig	fly	---
16-Jul	21-Jul	---	11	9	---	308	310	---	jig	fly	---
14-Jul	22-Jul	---	2	11	---	278	251	---	jig	fly	---

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Date	Recapture Date		River Mile			Length (mm FL)			Gear Type		
of release	Event 2	Event 3	Release	Event 2	Event 3	Release	Event 2	Event 3	Release	Event 2	Event 3
16-Jul	22-Jul	---	14	12	---	282	285	---	jig	fly	---
16-Jul	22-Jul	---	12	12	---	364	368	---	jig	fly	---
16-Jul	23-Jul	---	14	14	---	383	381	---	jig	fly	---
17-Jul	23-Jul	11-Aug	7	7	3	336	343	342	jig	fly	fly
17-Jul	23-Jul	---	7	7	---	299	295	---	jig	fly	---
13-Jul	24-Jul	---	12	12	---	374	381	---	jig	fly	---
16-Jul	24-Jul	---	14	13	---	328	327	---	jig	fly	---
14-Jul	20-Jul	---	4	4	---	333	unk	---	jig	jig	---
16-Jul	21-Jul	---	14	13	---	360	360	---	jig	jig	---
16-Jul	21-Jul	---	14	12	---	406	403	---	jig	jig	---
14-Jul	22-Jul	14-Aug	2	2	4	274	275	282	jig	jig	jig
14-Jul	22-Jul	---	2	2	---	265	265	---	jig	jig	---
14-Jul	22-Jul	---	2	2	---	282	282	---	jig	jig	---
14-Jul	22-Jul	---	2	2	---	272	273	---	jig	jig	---
14-Jul	22-Jul	---	2	2	---	260	270	---	jig	jig	---
14-Jul	22-Jul	---	2	2	---	255	250	---	jig	jig	---
15-Jul	22-Jul	---	5	2	---	273	270	---	jig	jig	---
16-Jul	23-Jul	---	14	14	---	350	351	---	jig	jig	---
16-Jul	23-Jul	---	14	14	---	363	366	---	jig	jig	---
16-Jul	23-Jul	---	14	14	---	365	355	---	jig	jig	---
16-Jul	23-Jul	---	14	14	---	380	377	---	jig	jig	---
16-Jul	23-Jul	---	14	3	---	390	390	---	jig	jig	---
16-Jul	23-Jul	---	12	3	---	364	358	---	jig	jig	---
16-Jul	23-Jul	---	10	7	---	383	382	---	jig	jig	---
14-Jul	24-Jul	---	4	5	---	346	302	---	jig	jig	---
15-Jul	24-Jul	---	9	5	---	392	392	---	jig	jig	---
16-Jul	24-Jul	---	12	5	---	361	360	---	jig	jig	---
15-Jul	21-Jul	---	9	9	---	320	322	---	jig	spin	---

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Date	Recapture Date		River Mile			Length (mm FL)			Gear Type		
of release	Event 2	Event 3	Release	Event 2	Event 3	Release	Event 2	Event 3	Release	Event 2	Event 3
14-Jul	---	10-Aug	4	---	6	350	---	348	spin	---	unk
14-Jul	---	12-Aug	4	---	4	335	---	359	spin	---	fly
14-Jul	---	14-Aug	4	---	4	266	---	271	spin	---	jig
14-Jul	20-Jul	10-Aug	4	4	13	259	260	unk	spin	fly	fly
14-Jul	23-Jul	---	4	7	---	279	282	---	spin	fly	---
14-Jul	22-Jul	---	4	2	---	264	270	---	spin	jig	---
14-Jul	22-Jul	---	4	2	---	340	344	---	spin	jig	---
14-Jul	23-Jul	---	3	3	---	290	297	---	spin	jig	---
13-Jul	---	10-Aug	14	---	14	285	---	278	unk	---	fly
13-Jul	---	10-Aug	14	---	14	395	---	400	unk	---	fly
13-Jul	---	12-Aug	6	---	4	287	---	297	unk	---	fly
13-Jul	---	14-Aug	14	---	4	332	---	344	unk	---	jig
13-Jul	22-Jul	---	unk	12	---	unk	403	---	unk	fly	---
13-Jul	22-Jul	---	14	11	---	265	289	---	unk	fly	---
20-Jul	---	10-Aug	6	---	7	293	---	302	fly	---	fly
20-Jul	---	10-Aug	6	---	6	387	---	387	fly	---	fly
20-Jul	---	11-Aug	10	---	11	323	---	329	fly	---	fly
20-Jul	---	11-Aug	6	---	11	272	---	279	fly	---	fly
20-Jul	---	11-Aug	4	---	4	305	---	317	fly	---	fly
20-Jul	---	11-Aug	4	---	4	250	---	257	fly	---	fly
20-Jul	---	11-Aug	4	---	4	300	---	301	fly	---	fly
20-Jul	---	11-Aug	4	---	4	280	---	284	fly	---	fly
20-Jul	---	13-Aug	4	---	5	385	---	404	fly	---	fly
21-Jul	---	10-Aug	13	---	13	280	---	290	fly	---	fly
21-Jul	---	10-Aug	11	---	14	387	---	381	fly	---	fly
21-Jul	---	11-Aug	11	---	11	358	---	360	fly	---	fly
21-Jul	---	11-Aug	11	---	11	359	---	358	fly	---	fly
21-Jul	---	11-Aug	11	---	11	281	---	282	fly	---	fly

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Date	Recapture Date		River Mile			Length (mm FL)			Gear Type		
of release	Event 2	Event 3	Release	Event 2	Event 3	Release	Event 2	Event 3	Release	Event 2	Event 3
21-Jul	---	11-Aug	11	---	11	317	---	327	fly	---	fly
21-Jul	---	11-Aug	11	---	12	365	---	371	fly	---	fly
21-Jul	---	11-Aug	11	---	11	390	---	385	fly	---	fly
21-Jul	---	11-Aug	9	---	12	328	---	323	fly	---	fly
21-Jul	---	12-Aug	11	---	4	277	---	286	fly	---	fly
21-Jul	---	13-Aug	9	---	9	280	---	295	fly	---	fly
21-Jul	---	13-Aug	9	---	9	262	---	270	fly	---	fly
21-Jul	---	13-Aug	9	---	9	253	---	262	fly	---	fly
21-Jul	---	13-Aug	5	---	5	320	---	325	fly	---	fly
22-Jul	---	10-Aug	7	---	7	305	---	312	fly	---	fly
22-Jul	---	10-Aug	7	---	7	346	---	348	fly	---	fly
22-Jul	---	10-Aug	7	---	7	378	---	375	fly	---	fly
22-Jul	---	10-Aug	7	---	7	408	---	410	fly	---	fly
22-Jul	---	11-Aug	12	---	12	393	---	401	fly	---	fly
22-Jul	---	11-Aug	12	---	12	358	---	358	fly	---	fly
22-Jul	---	13-Aug	8	---	8	297	---	303	fly	---	fly
22-Jul	---	13-Aug	8	---	8	371	---	376	fly	---	fly
23-Jul	---	10-Aug	7	---	7	288	---	291	fly	---	fly
23-Jul	---	12-Aug	7	---	10	414	---	413	fly	---	fly
24-Jul	---	11-Aug	13	---	12	285	---	287	fly	---	fly
24-Jul	---	11-Aug	12	---	11	284	---	292	fly	---	fly
24-Jul	---	11-Aug	12	---	11	407	---	411	fly	---	fly
24-Jul	---	11-Aug	12	---	11	291	---	298	fly	---	fly
24-Jul	---	11-Aug	12	---	11	340	---	341	fly	---	fly
24-Jul	---	12-Aug	12	---	12	359	---	359	fly	---	fly
20-Jul	---	12-Aug	4	---	4	294	---	300	fly	---	jig
21-Jul	---	10-Aug	9	---	13	390	---	389	fly	---	jig
21-Jul	---	11-Aug	11	---	11	437	---	438	fly	---	jig

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Date	Recapture Date		River Mile			Length (mm FL)			Gear Type		
of release	Event 2	Event 3	Release	Event 2	Event 3	Release	Event 2	Event 3	Release	Event 2	Event 3
21-Jul	---	11-Aug	11	---	11	355	---	356	fly	---	jig
21-Jul	---	13-Aug	11	---	5	319	---	321	fly	---	jig
22-Jul	---	13-Aug	11	---	5	296	---	345	fly	---	jig
22-Jul	---	13-Aug	9	---	9	244	---	303	fly	---	jig
23-Jul	---	11-Aug	13	---	3	373	---	368	fly	---	jig
20-Jul	---	10-Aug	6	---	6	324	---	326	fly	---	unk
20-Jul	---	11-Aug	4	---	4	320	---	332	jig	---	fly
20-Jul	---	11-Aug	4	---	4	402	---	401	jig	---	fly
20-Jul	---	12-Aug	10	---	10	388	---	395	jig	---	fly
21-Jul	---	10-Aug	13	---	13	304	---	323	jig	---	fly
21-Jul	---	11-Aug	13	---	12	313	---	322	jig	---	fly
21-Jul	---	11-Aug	12	---	11	305	---	310	jig	---	fly
21-Jul	---	12-Aug	13	---	4	328	---	338	jig	---	fly
21-Jul	---	13-Aug	13	---	8	384	---	387	jig	---	fly
22-Jul	---	10-Aug	7	---	7	364	---	367	jig	---	fly
22-Jul	---	11-Aug	11	---	4	387	---	385	jig	---	fly
22-Jul	---	11-Aug	11	---	4	260	---	268	jig	---	fly
22-Jul	---	12-Aug	11	---	10	385	---	385	jig	---	fly
22-Jul	---	13-Aug	11	---	8	292	---	308	jig	---	fly
22-Jul	---	13-Aug	2	---	9	304	---	309	jig	---	fly
23-Jul	---	10-Aug	13	---	14	359	---	358	jig	---	fly
23-Jul	---	10-Aug	7	---	7	356	---	359	jig	---	fly
23-Jul	---	11-Aug	3	---	3	320	---	325	jig	---	fly
24-Jul	---	12-Aug	13	---	12	402	---	404	jig	---	fly
20-Jul	---	12-Aug	10	---	10	360	---	367	jig	---	jig
20-Jul	---	12-Aug	4	---	4	331	---	331	jig	---	jig
21-Jul	---	10-Aug	13	---	6	319	---	322	jig	---	jig
22-Jul	---	11-Aug	2	---	3	297	---	300	jig	---	jig

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Date	Recapture Date		River Mile			Length (mm FL)			Gear Type		
of release	Event 2	Event 3	Release	Event 2	Event 3	Release	Event 2	Event 3	Release	Event 2	Event 3
22-Jul	---	12-Aug	7	---	10	334	---	335	jig	---	jig
23-Jul	---	10-Aug	13	---	14	355	---	354	jig	---	jig
23-Jul	---	11-Aug	3	---	3	330	---	333	jig	---	jig
23-Jul	---	11-Aug	3	---	3	317	---	320	jig	---	jig
23-Jul	---	11-Aug	3	---	3	289	---	285	jig	---	jig
23-Jul	---	12-Aug	13	---	15	385	---	384	jig	---	jig
24-Jul	---	13-Aug	5	---	5	345	---	348	jig	---	jig
24-Jul	---	14-Aug	5	---	4	368	---	371	jig	---	jig
21-Jul	---	10-Aug	12	---	6	350	---	353	jig	---	unk
20-Jul	---	11-Aug	4	---	4	280	---	270	unk	---	fly
21-Jul	---	10-Aug	13	---	14	305	---	305	unk	---	jig
21-Jul	---	12-Aug	13	---	10	409	---	407	unk	---	jig
21-Jul	---	13-Aug	13	---	9	348	---	350	unk	---	jig

Appendix A13.-Summary of estimates of abundance and recruitment and standard errors for Arctic grayling in the Delta Clearwater River, 1977 = 1998.

Year	N[150]	SE[N150]	N[240]	SE[N240]	N[270]	SE[N270]	N[Age 5+][a]	SE[Age 5+]	Recruitment N[Age 5][a]	Recruitment SE[Age 5]
1977	nd	---	nd	---	nd	---	9,702	1,234	5,862	1,335
1978	nd	---	nd	---	nd	---	8,826	1,279	4,461	1,484
1979	nd	---	nd	---	nd	---	6,258	885	4,134	1,146
1980	nd	---	nd	---	nd	---	6,175	832	3,467	856
1981	nd	---	nd	---	nd	---	9,829	1,461	6,907	1,640
1982	nd	---	nd	---	nd	---	9,369	1,159	4,554	1,173
1983	nd	---	nd	---	nd	---	12,760	1,746	7,828	1,999
1984	nd	---	nd	---	nd	---	11,063	1,276	4,931	1,295
1985	nd	---	nd	---	nd	---	10,767	1,388	4,458	1,267
1986	nd	---	nd	---	nd	---	7,840	1,148	2,724	708
1987	nd	---	nd	---	nd	---	7,684	1,289	3,571	933
1988	nd	---	nd	---	nd	---	8,845	1,962	1,957	578
1989	nd	---	nd	---	nd	---	6,482	1,751	2,420	601
1990	nd	---	nd	---	nd	---	4,477	1,766	2,301	619
1991	nd	---	nd	---	nd	---	nd	---	1,754	686
1992	nd	---	nd	---	nd	---	nd	---	2,219	1,066
1993	nd	---	nd	---	nd	---	nd	---	945	692
1994	nd	---	nd	---	nd	---	nd	---	1,179	1,491
1995	nd	---	nd	---	nd	---	nd	---	nd	---
1996	nd	---	3,000	370	2,750	340	2,490	310	670	100
1997	9,000	920	7,420	920	6,490	800	4,600	590	810	140
1998	nd	---	5,570	780	4,740	480	4,500	630	1,820	300
Average	9,000	---	5,330	---	4,660	---	7,745	---	3,284	---

[a] Estimates for 1977 - 1990 are from CAGEAN modeling (Clark and Ridder 1994) and reflect population at start of fishing season. Estimates for 1996 - 1998 are from mark-recapture experiments (Ridder 1998b and this report) and reflect population in July.

APPENDIX B
DATA FILE LISTING

Appendix B1.-Data files[a] for all Arctic grayling captured in the Delta Clearwater River, 1998.

Data file	Description
U-000600L011998	Sample data from 13-17 July 1998.
U-000600L011998	Sample data from 20-24 July 1998.
U-000600L011998	Sample data from 10-14 August 1998.

[a] Data files are archived at and are available from the Alaska Department of Fish and Game, Sport Fish Division, Research and Technical Services, 333 Raspberry Road, Anchorage, Alaska 99518-1599.

APPENDIX C
ESTIMATION OF ABUNDANCE WITHOUT CAPTURE GEAR DATA

Appendix C1.-Abundance estimator.

Abundance Estimator:

Estimated abundance, $\hat{N}$, was calculated from numbers of Arctic grayling marked, examined for marks, and recaptured (Bailey 1951; Seber 1982):

$$\hat{N} = \frac{M(C+1)}{R+1}, \tag{C1}$$

where:

M = the number of Arctic grayling marked and released alive during the first sample;

C = the number of Arctic grayling examined for marks during the second sample; R = the number of Arctic grayling recaptured during the second sample; and,

Variance was estimated by (Seber 1982):

$$\hat{V}\left[\hat{N}\right] = \frac{M^2(C+1)(C-R)}{(R+1)^2(R+2)} \tag{C2}$$

Bailey's (1951, 1952) modification was used instead of the modification by Chapman (1951) because of the systematic sampling design used in the experiment. Seber (1982) found that if the assumption of a random sample for the second sample was false and a systematic sample was taken, then the binomial model of Bailey (1951, 1952) is appropriate. The binomial model will hold in this situation when:

1. there is uniform mixing of marked and unmarked fish; and,
2. all fish, whether marked or unmarked, have the same probability of capture.

The sample design did not allow for thorough mixing of fish marked at the uppermost reaches with those marked in the downstream reaches, although local mixing of marked and unmarked fish likely occurred since fish were released where captured.

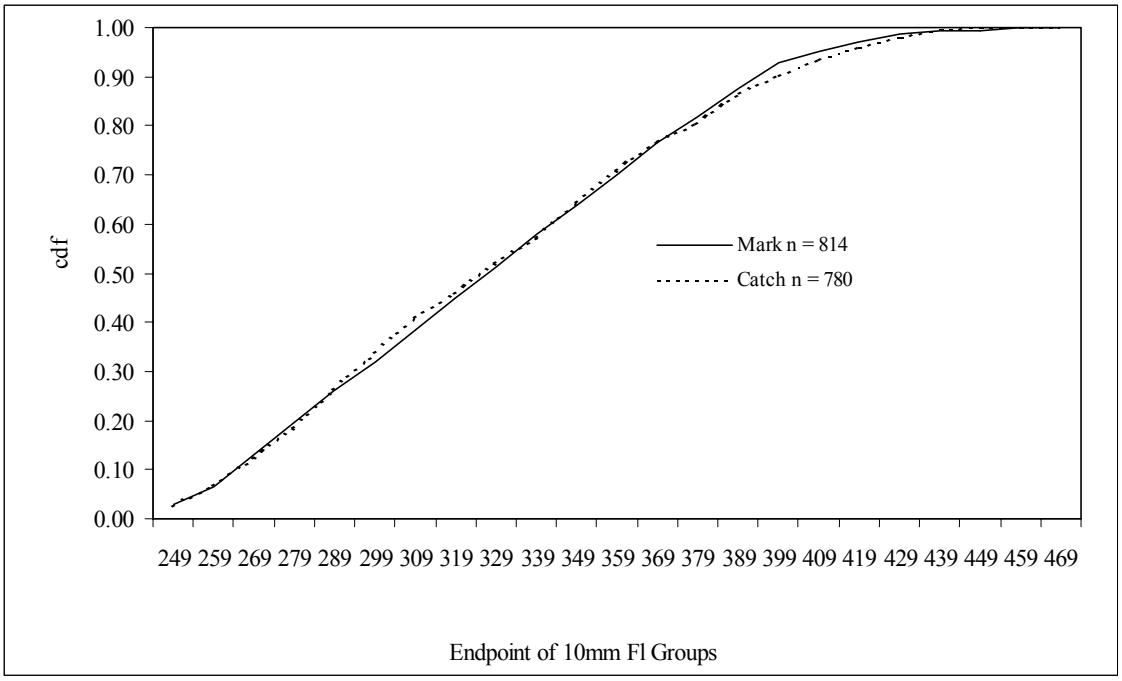
-continued-

ABUNDANCE

Abundance was estimated with two 5-d events within a two-week period. The hiatus between events on any river mi averaged 7 days. The target population for abundance estimation was truncated to fish ≥ 240 mm (Table 2) since the smallest fish recaptured was 240 mm. During the first event, 13-17 July, 818 fish ≥240 mm FL were released alive with marks. During the second event, 20-24 July, 780 fish ≥240 mm FL were captured including 105 fish recaptured from the first (marking) event.

Size bias was not significant during either event, therefore size stratification was not necessary (P = 0.07 and P = 0.66; Appendix C2. Area stratification was not necessary since capture probabilities between the three sections were not significantly different (χ^2 = 2.68, df = 2, P=0.26; Appendix C3.

Estimated abundance of fish ≥240 mm FL was 5,997 (SE = 539), of fish ≥270 mm was 5,226 (SE = 470; Appendix C4 and, of fish of Age 5 and older was 4,970 (SE = 460; Appendix C5.



Appendix C2.-Cumulative distribution functions (cdf) of 10 mm fork length groups of Arctic grayling ≥240 mm FL marked, captured, and recaptured in the Delta Clearwater River, 13 through 23 July 1998.

Appendix C3.-Data summary for movements of 103 of 105 recaptured Arctic grayling ≥240 mm FL in the Delta Clearwater River 1998 mark-recapture experiment.

Mark Location	Marks	Recapture Location			R/M[a]
		Lower	Middle	Upper	
Lower	214	24	1	1	0.15
Middle	273	2	19	0	0.08
Upper	331	6	2	48	0.15
Total	818	32	22	49	0.13
Examined without marks=		200	196	281	
R/C[b=]		0.14	0.10	0.15	

[a] R/M = recapture rate, number of recaptures divided by number of marked fish released in the first event.

[b] R/C = capture probability, number of recaptures divided by number of fish examined in second event.

Appendix C4.-Relative Stock Density (RSD) indices of captured Arctic grayling ≥150 mm FL with abundance and standard errors for fish ≥ 240 mm FL, Delta Clearwater River, July and August 1998.

Category	Length (mm FL)	n	RSD	SE[RSD]	N	SE[N]
		July				
Stock	150 - 269	240 (192)[a]	0.16	0.01	(771)	(86)
Quality	270 - 339	681	0.46	0.01	2,734	257
Preferred	340 - 449	616	0.41	0.01	2,473	235
Memorable	450 - 559	5	<0.01	<0.01	20	9
Trophy	≥560	0	---	---	---	---
Total		1,542 (1,494)	1.00	---	(5,997)	(539)
Quality+	≥270	1302	0.87	0.01	5,226	473
		August				
Stock	150 - 269	47 (37)	0.06	0.01	---	---
Quality	270 - 339	359	0.50	0.02	---	---
Preferred	340 - 449	316	0.44	0.02	---	---
Memorable	450 - 559	2	<0.01	<0.01	---	---
Trophy	≥560	0	---	---	---	---
Total		724 (714)	1.00	---	---	---
Quality+	≥270	677	0.94	0.01	---	---

[a] (x) represents only fish ≥ 240 mm FL

Appendix C5.-Estimates of age composition and abundance by age class with standard errors and coefficient of variation (CV) for Arctic grayling (≥240 mm FL), Delta Clearwater River, July 1998.

	Age Composition			Abundance		
Age Class	n	p	SE[p]	N	SE[N]	CV
3	18	0.03	0.01	174	43	25%
4	89	0.14	0.01	858	114	13%
5	188	0.30	0.02	1,813	197	11%
6	85	0.14	0.01	820	110	13%
7	94	0.15	0.01	906	118	13%
8	72	0.12	0.01	694	99	14%
9	30	0.05	0.01	289	58	20%
10	17	0.03	0.01	164	42	25%
11	15	0.02	0.01	145	39	27%
12	7	0.01	0.00	67	26	39%
13	6	0.01	0.00	58	24	41%
14	1	0.00	0.00	10	10	100%
Total	622	---	---	5,997	539	9%
5+	515	0.83	0.02	4,965	455	9%

APPENDIX D

Appendix D1.-Data for Darroch model analysis with fly caught marks.

		Recaptures by location (C)		
Mark location	Marks (a)	Lower	Middle	Upper
Lower	56	8	0	0
Middle	153	1	11	0
Upper	173	3	1	35
Catches without marks (b)		200	196	280

Appendix D2.-Darroch model parameter estimates.

Mark Location	Capture Probability	Theta		
		Low	Middle	Upper
Lower	**0.115**	**1**	**0**	**0**
Middle	0.081	0.1	0.9	0
Upper	0.268	0.2	0.05	0.75